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The Alternative Fuel Transition:

Results from the TAFV Model of Alternative Fuel Use in Light-Duty Vehicles 1996 -2010

Final Report - TAFV Version 1

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Abstract

Section 502(b) of the Energy Policy Act of 1992 (EPACT) requires that the Secretary of Energy estimate the technical and economic feasibility of producing sufficient replacement fuels to replace, on an energy equivalent basis, at least 10 percent of motor fuel use by the year 2000; and at least 30 percent by the year 2010. Earlier analysis using a single-period equilibrium model demonstrated the feasibility of EPACT's goals. This earlier analysis assumed mature markets: large-scale vehicle production and the widespread availability of alternative fuels at retail stations. These conditions are not currently attained by the market for alternative fuels and vehicles. To better characterize the introduction of alternative fuels and vehicles, the Transitional Alternative Fuels and Vehicles (TAFV) Model simulates the use and cost of alternative fuels and vehicles over the time period of 1996 to 2010. It is designed to examine the *transitional* period of alternative fuel and vehicle use, considering possible barriers related to infrastructural needs and production scale. It accounts for dynamic linkages between investments and vehicle and fuel production capacity, tracks vehicle stock evolution, and represents the effects of increasing scale and expanding retail fuel availability on the effective costs to consumers. Fuel and vehicle prices and choices are endogenous. As a dynamic transitional model, it can help to assess what may be necessary to achieve mature, large scale, alternative fuel and vehicle markets, and what it may cost. Various policy cases are considered including fleet vehicle purchase mandates, fuel subsidies, and tax incentives for low greenhouse gas emitting fuels.

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Acronyms and Abbreviations

AEO Annual Energy Outlook
AEO98 Annual Energy Outlook 1998
AF Alternative fuel
AFTM Alternative Fuels Trade Model
AFV Alternative-fuel vehicle
AMFA Alternative Motor Fuels Act of 1988
BBL Barrel
Bcf Billion cubic feet
Bge Barrel of gasoline equivalent
Btu British thermal unit
CNG Compressed natural gas
CO_2 Carbon dioxide
Ded Dedicated
DFV Dual-fuel vehicle
E100 100 % ethanol
E85 85 % ethanol and 15 % gasoline
EIA Energy Information Administration
EPACT Energy Policy Act of 1992
ETBE Ethyl tertiary-butyl ether
ETC Ethanol tax credit
EV Electric vehicle
FFV Flexible-fuel vehicle
FFV Flexible-fuel vehicle
G Gram
Gal Gallon
GGE Gasoline gallon equivalent
GHG Greenhouse gas
GWP Global warming potential
HWOP High world oil price
Kg Kilogram
KWh Kilowatt hour
Lb Pound
LDT Light-duty truck
LDV Light-duty vehicle
LGHGTC Low GHG tax credit
LPG Liquefied petroleum gas
M85 85 % methanol and 15 % gasoline
MCF Thousand cubic feet
Mi Mile
Mmbd Million barrels per day
MMBGE Million barrels gasoline equivalent
MMBGED Million barrels gasoline equivalent per day
MMBTU Million British thermal units
MT Metric ton
NPV Net present value
PNGV Partnership for a New Generation Vehicle
SRWC Short rotation woody crop
TAFV Transitional Alternative Fuels and Vehicles
USDOE U.S. Department of Energy

Executive Summary

Section 502(b) of the Energy Policy Act of 1992 (EPACT) requires that the Secretary of Energy estimate the technical and economic feasibility of producing sufficient replacement fuels to replace, on an energy equivalent basis, at least 10 percent of motor fuel use by the year 2000; and at least 30 percent by the year 2010. Earlier analysis using a single-period equilibrium model demonstrated the feasibility of EPACT's goals. This earlier analysis assumed mature markets: large-scale vehicle production and the widespread availability of alternative fuels at retail stations. These conditions are not currently attained by the market for alternative fuels and vehicles. To better characterize the introduction of alternative fuels and vehicles, the Transitional Alternative Fuels Vehicle (TAFV) Model simulates the use and cost of alternative fuels and vehicles over the time period of 1996 to 2010. It is designed to examine the *transitional* period of alternative fuel and vehicle use, considering possible barriers related to infrastructural needs and production scale. It accounts for dynamic linkages between investments and vehicle and fuel production capacity, tracks vehicle stock evolution, and represents the effects of increasing scale and expanding retail fuel availability on the effective costs to consumers. Fuel and vehicle prices and choices are endogenous. As a dynamic transitional model, it can help to assess what may be necessary to achieve mature, large scale, alternative fuel and vehicle markets, and what it may cost. Various policy cases are considered including fleet vehicle purchase mandates, fuel subsidies, and tax incentives for low greenhouse gas emitting fuels.

The cases explored here differ from those in our previous draft studies of the transition (Leiby and Rubin, February, 1998) in that the basic cost assumptions were modified in three ways that are less favorable to alternative fuels. First, they employ DOE's AEO98 projections for future gasoline price shown in Table 1.[1] Second, the ethanol tax credit, while now extended through 2007, declines somewhat in nominal terms, and is assumed to decline even faster in real terms, given a 3% inflation rate over the forecast horizon. Third, the costs of producing ethanol from cellulosic biomass were re-estimated given newer understanding about the technologies and the economics of crops and farm land. Fourth, the alternative fuel tax incentives (credits, such as the ethanol tax credit) are now assumed to be stated in nominal dollars, and to decline in real terms with 3% inflation. This reduces their power.

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[1]Bowman, Leiby and Rubin, 1998, summarizes the recent work in updating (benchmarking) the Transitional Alternative Fuel and Vehicles (TAFV) model with the latest estimates from the Annual Energy Outlook 1998 (AEO98). Previous versions of the TAFV were benchmarked to the AEO96. It details the AEO98 retail motor fuel price projections and their components, and then compares them to the fuel prices in the previously used AEO96.

Table E-1: AEO98 Retail Fuel Price Components ($94/GGE)					
Year 1996					
Fuel	**E85**	**Gasoline**	**LPG**	**M85**	**CNG**
Plantgate	1.77	0.68	0.49	NA	0.25
Markups	0.29	0.13	0.64	0.24	0.24
Taxes	-0.21	0.36	0.37	0.41	0.15
Retail Price	1.85	1.18	1.50	NA	0.64
Year 2010					
Fuel	**E85**	**Gasoline**	**LPG**	**M85**	**CNG**
Plantgate	1.82	0.77	0.62	NA	0.27
Markups	0.29	0.14	0.66	0.24	0.38
Taxes	-0.07	0.31	0.31	0.36	0.14
Retail Price	2.04	1.21	1.58	NA	0.79
Note: Some assumptions were necessary to complete this table. See Bowman, Leiby and Rubin, 1998.					

Result Highlights

Below are some important insights from the complete TAFV-version 1 runs.

E1. Overall, we find that the market barriers to significant alternative fuel and vehicle use are substantial. Consistent with earlier draft cases, we still find that in the absence of any new policy initiatives, it may be difficult for the alternative vehicle and fuel markets to get started. The base case yields almost no alternative fuel and AFV penetration. For the AEO98 base oil price path, current policies (i.e., current EPACT fleet mandates, fuel taxes, and CAFE credits for AFVs), appear inadequate to induce any significant alternative fuel use, or any AFV purchases beyond the minimum mandated by the law.

E2. More remarkably, if the DOE/EIA base case oil price projections from AEO98 hold true, even some substantial new AFV/AF incentives may have only limited effect. For example, the continuation of the ethanol tax credit beyond 2007 may be inadequate to induce ethanol (or other) alternative fuel use. This is assuming that the ethanol tax credit is specified in nominal terms, and is allowed to decline in real terms each year with 3% inflation.

E3. The long-run, no-barriers case is useful to assess what AFV/AF penetration might be expected if there were no transitional barriers to their introduction, other than the usual gradual turnover of vehicle stock. The no-transitional-barriers case explores what would happen if alternative fuels and vehicles were produced at large scale costs, and fuel availability and vehicle diversity pose no effective cost to consumers. The long-run, no-barriers case projects a 14.9% displacement of gasoline by alternative fuels in the year 2010, including 8.4% displacement by blends and a 6.5% displacement by neat fuels M85, CNG, and LPG. *Provided* we assume that AEO98 High World Oil Price projections and the lower-cost LPG projections embodied in the AFTM are correct, the 2010 gasoline displacement in the no-barriers case is 25.5% by 2010 (including 7.1% displacement by blends and 18.4% displacement by neat fuels). The bottom line is that under the recent DOE projections of gasoline and alternative fuel costs, alternative fuels are just not highly competitive, even in a mature market.

E4. A rule mandating Private and Local (P&L) fleets, induces AFV purchases from households. With the Local and Private Rule, voluntary household AFV purchases climb to 2.9 % from 1.2% in the base case by 2010.

E5. However, given the high cost of alternative fuels, the Local and Private Rule does not induce private AFV owners to use alternative fuels in their voluntarily-purchased alcohol FFVs. As in the base case, various alternative fuels make up the 0.12% of total fuel use by 2010.

E6. The Retail Fuel Mandate Case requires that sufficient alternative fuels be sold to meet EPACT displacement targets. (We are silent about exactly how this might be implemented, we simply impose it as a retail fuel sales constraint). In this case, given base assumptions about oil and LPG prices, there is a major contribution by methanol, much of which is imported. If the ethanol tax credit is increased to offset inflation, then E85 also plays a role, reaching about 6% use by 2006-2007, but then shutting down in 2008 with lapsing of ethanol tax credit.

E7. Petroleum is displaced by the use of “neat” alternative fuels as well as through the use of reformulated and oxygenated gasolines which contain natural gas, hydrogen, and alcohol and ether-oxygenates Thus, the quantity of petroleum displaced will always be greater than the quantity (of energy adjusted) alternative fuel used. In the base case, 9.1% and 9.2% of petroleum is displaced in the years 2000 and 2010, respectively. The quantity displaced is virtually the same in both years because the is very little alternative fuel use and the ratio of reformulated to conventional gasoline is held constant over the model's time horizon. This result is not sensitive to our assumptions concerning world oil prices or the cost of LPG. In the base case, across all of our input price scenarios, the quantity of oil displaced simply does not vary. Thus, we can conclude that, in the absence of new policy initiatives, that the US is not likely to attain EPACT's 2000 or 2010 fuel displacement goals.

E8. Some of the policies we have examined do, however, lead to a significant quantity of fuel displacement. As expected, the mandated retail alternative fuel sales requirement case achieves the 30% replacement goal by 2010. What makes this case of interest is not that it achieves mandated gasoline displacement, but the freely chosen mix of fuels and vehicles which comprise the mandated mix. In addition, the net cost to consumers, fuel producers and vehicle manufacturers of attaining this goal is important. Using the base fuel prices, we project that a retail alternative fuel mandate requiring 30% displacement of petroleum will be satisfied by the use of imported methanol (23%), oxygenate blends (6%), and very small quantities of LPG and ethanol (1% combined). This mix does not change in the presence of higher world oil prices, nor if the ethanol tax credit is indexed for inflation. The one case in which the mix changes substantially, is if LPG is available at a lower price (about $0.30/GGE less expensive) comparable to that used in DOE's prior market potential study (AFTM, USDOE 1996, Leiby 1993). In this case LPG displaces 15% of petroleum with the remaining displacement coming from methanol and oxygenate blends.

E9. In the no transitional barriers case, 14.9% of oil is displaced using base case fuel prices. Other fuel price assumptions increase this displacement level. With high world oil prices and high LPG costs, petroleum displacement rises to 18% by 2010. If lower LPG costs are also available, then in the absence of transitional barriers, we find that petroleum displacement would be 25%. Thus, the TAFV model, using fuel price assumptions close to those of the 1996 DOE study of static market potential, finds similar levels of petroleum displacement.

E10. Other than the alternative fuel sales mandate policy, the policies that are most effective in inducing the displacement of petroleum are the Low-GHG Tax Credit and the Continued Ethanol Tax Credit. Both of these policies rely on substantial subsidization of ethanol and other low GHG fuels. Given base case fuel price projections, these policies are not sufficient to induce additional alternative fuel penetration. Given High World Oil Prices (HWOP cases), however, these policies can be effective, particularly if the ethanol tax credit is adjusted for inflation to maintain its present value of $0.54 per physical gallon. Given high world oil prices, the Low-GHG Tax Credit induces petroleum displacement from 9.3% to 11.3% by 2010. If, in addition, the subsidy in the Low-GHG Tax Credit case is also inflation adjusted, 22% of petroleum can be displaced by 2010. The Continued Ethanol Tax Credit Policy Case is less effective since it only targets ethanol, rather than all low-GHG fuels. Nonetheless, it is able to induce a 16% displacement of petroleum if the tax credit is inflation adjusted.

E11. Overall, the TAFV base case projection from 1996 to 2000 does a moderately good job of back-casting recent history. Total AFV stocks are accurate to within 15 percent, and the mix of vehicles chosen by the model is fairly close to EIA historical data. While the demand for alcohol fuels is over-projected, and the demand for LPG was under-projected, the quantities involved are small. In broad terms, the TAFV results match recent historical outcomes well: very little alternative fuel is being demanded (on the order of 0.1% of total fuel demand by light-duty vehicles).

Table E-2 summarizes some of the fuel displacement and welfare cost results given the base-case assumptions on fuel prices. Many more results are available in summary Tables 7, 8, 9, 10, 11, 12. As can be seen, the effectiveness and average cost of the various policies vary widely. In each of the cases The welfare cost is the discounted sum of consumer and producer surplus net of any taxes or subsidies over the 1996-2010 time horizon, plus any costs or benefits associated with the terminal period, relative to the base case or current policy.

Table E-2: Fuel Displacement Summary Table
AEO Base, Higher LPG Cost

Policy	Gasoline Displacement in 2010*	Total Displacement 1996-2010	Welfare Cost**	Incremental Displacement Cost***
Units	Percent	Billion GGE	Billion $96	$/GGE
Base (No Policy)	9.2%	178.82	0.000	NA
Late Private (P&L) Rule	9.2%	178.80	1.721	NA
Late Private Rule with 50% Fuel Mandate	9.7%	183.18	3.944	1.56
Continued Ethanol Tax Credit	9.2%	178.88	0.038	0.46
Low-GHG Fuel Subsidy	9.3%	179.07	1.267	0.44
Increased CAFE Standards	9.2%	178.85	0.309	0.36
Retail Alternative Fuel Sales Mandate	30.0%	343.40	26.567	0.29
Ensign Bill: $0.50 AF credit thru 2004	9.2%	180.25	0.226	0.28
Extended Ensign Bill: $0.25 AF credit thru 2009	9.3%	180.15	0.196	0.26
Extended Ensign Bill: $0.50 AF credit thru 2009	9.3%	181.17	0.370	0.29
No Transitional Barriers (Long-Run)	14.9%	224.20	NA	NA
P&L Rule Plus Continued Ethanol Tax Credit	9.3%	179.16	1.804	8.35
P&L Rule Plus Low-GHG Fuel Subsidy	9.3%	179.59	1.904	4.07
P&L Rule Plus Increased CAFE Standards	9.3%	179.35	2.371	3.10

* Includes displacement from both alternative fuels and replacement fuels, including the replacement fuel content of gasoline.
**The welfare cost is the discounted sum of consumer and producer surplus net of any taxes or subsidies over the 1996-2010 time horizon plus any costs or benefits associated with the terminal period, relative to Base/current policy.
*** The cost per gallon is the discounted welfare cost divided by the discounted sum of fuel displacement over the 1996-2010 time horizon plus any costs, benefits and displacement associated with the terminal period.

These results lead us to several observations. First, in a market economy where vehicle manufacturers, fuel suppliers, and consumers all make independent decisions, the efficacy of government policies to reduce the dependence of the United States transportation sector on petroleum is highly dependent on the world price of petroleum. Second, the penetration of alternative fuels and AFVs depends on the fuel retail infrastructure, the ability to achieve large-scale AFV production, and other transitional barriers. Absent new government policies to reduce these transitional barriers, it is likely that the United States will not achieve EPACT's 2000 and 2010 displacement goals. Governmental policies can effectively reduce these barriers and can allow alternative fuels to compete in the marketplace with gasoline. However, given the current and expected low price of petroleum in the world today, the policies that we have examined are not likely to be sufficient.

1.0 Introduction and Overview

Pursuant to Section 502(a) of the Energy Policy Act of 1992 (EPACT) the Secretary of Energy is required to establish a program to promote the development and use in light duty motor vehicles of domestic replacement and alternative fuels. Further, such a program should, to the extent practicable, ensure the availability of those replacement fuels that will have the greatest impact in reducing oil imports, improving the health of our Nation's economy and reducing greenhouse gas emissions. Section 502(b) of EPACT requires that the Secretary, among other things, estimate the technical and economic feasibility of achieving the goals of producing sufficient replacement fuels to replace, on an energy equivalent basis, at least 10 percent of motor fuel use by the year 2000; and at least 30 percent by the year 2010, with at least one half of such replacement fuels being domestic fuels, and determine the greenhouse gas emission implications of increasing the use of replacement fuels, including an estimate of the maximum feasible reduction in such emissions from the use of replacement fuels.[2]

In 1996, DOE published the results of their initial analysis of EPACT'S goals, using the Alternative Fuels Trade Model (AFTM, USDOE 1996, Leiby 1993). This study determined, among other things, that (p. xii): "For the year 2000, 10 percent replacement of light-duty motor fuel use with alternative and replacement fuels is feasible and appears likely with existing practices and policies." The USDOE report further stated: "Displacing 30 percent of light-duty motor fuel use by 2010 appears feasible. However, this estimated feasibility is based upon a number of assumptions that may not be realized without additional alternative-fuel initiatives." Consumption in 1998, however, of alternative and replacement fuels is estimated to account for 2.6 percent on a gasoline-gallon-equivalent (GGE) basis, of on-road transportation fuel use (EIA, 1997a, Table 10). Thus, it appears unlikely that the year 2000, 10 percent displacement goal will be realized. In addition, as described in detail in this report below, it is also quite unlikely for the year 2010, 30 percent displacement goal to be met absent significant new policy initiatives. On the other hand, some policy scenarios described below do approach EPACT's 2010 replacement goals. The results from these scenarios describe the investments in retail and vehicle production infrastructure that would be necessary for these policies to be successful.

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[2] According to EPACT (Section 301): "[T]he term 'replacement fuel' means the portion of any motor fuel that is methanol, ethanol, or other alcohols, natural gas, liquefied petroleum gas, hydrogen, coal derived liquid fuels, fuels (other than alcohol) derived from biological materials, electricity (including electricity from solar energy), ethers, or any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits." In addition, "the term 'alternative fuel' means methanol, denatured ethanol, and other alcohols; mixtures containing 85 percent or more (or such other percentage, but not less than 70 percent, as determined by the Secretary, by rule, to provide for requirements relating to cold start, safety, or vehicle functions) by volume of methanol, denatured ethanol, and other alcohols with gasoline or other fuels; natural gas; liquefied petroleum gas; hydrogen; coal-derived liquid fuels; fuels (other than alcohol) derived from biological materials; electricity (including electricity from solar energy); and any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits."

The reasons why this report's conclusions differs from those of the earlier study stems, mainly, from their different methodological approaches and because of the projected low price of gasoline that makes alternative fuels relatively less attractive than otherwise would be if gasoline were more expensive. The earlier AFTM model characterizes a static (one-period) equilibrium that assumes widespread availability of alternative fuels and vehicles. The AFTM model presents a 'snapshot' of alternative fuel and vehicle use assuming mature vehicle technologies produced at large scale and a well-developed alternative fuel retail sector. For alternative fuel and vehicles to achieve substantial energy security and emission benefits, however, it is necessary for them to be widely adopted. This requires large investments in fuel and vehicle infrastructure by private firms and individuals.

The Transitional Alternative Fuels and Vehicles (TAFV) Model, whose results are discussed in this report, simulates the use and cost of alternative fuels and alternative fuel vehicles over the time frame of 1996 to 2010. As the model's name suggests, the TAFV model is specifically designed to examine the *transitional* period of alternative fuel and vehicle use. That is, the model is a first attempt to characterize how the United States' market for AFVs might change from one based on new technologies available only at a higher-cost and lower-volume, to a world with more mature technologies offered at lower cost and wider scale. It explores the effectiveness of current policies authorized under EPACT and the Alternative Motor Fuels Act of 1988 (AMFA), as well as potential policies that would be necessary for this transition to happen.[3] By making the scale of alternative vehicle and fuel production and the retail availability of alternative fuels endogenous, the TAFV model fills a gap in alternative fuel analysis. In contrast to the AFTM, the TAFV model specifically characterizes the time path of investment and adjustment, in order to evaluate the importance of transitional barriers. The results from the TAFV model do, necessarily, reflect its many primary assumptions such as the prices for vehicle and fuel production capital, the costs of raw materials, and the input-output assumptions that describe the productivity of a unit of capital in its respective employment.

More generally, the TAFV model provides a methodology for simulating the introduction of new technologies where economies of scale and endogenous feedback effects are important. It is our belief that explicitly modeling these dynamic effects is very important and cannot be ignored for a wide variety of economic and environmental questions that involve either fixed investment in capital or pollution stocks such as greenhouse gas emissions.

[3]Other studies, which examine alternative fuels and vehicles in a multi-year, dynamic setting (e.g., Fulton 1994, Rubin 1994, and Kazimi, 1997) take technologies and prices as exogenously given. That is, they do not examine the important linkages between investments in alternative fuels and vehicles, investment in alternative fuel retailing infrastructure, and the prices and availability of those technologies.

1.1 Principal Objectives

The principal objective of the TAFV model is to provide a flexible, dynamic-simulation modeling tool that can be used for policy analysis. One use of the TAFV model is to assess possible ways in which AFV fleet mandates (authorized under EPACT) or incentives *may* influence the AFV transition. Because of its flexible design, the TAFV model is also able to examine many other policy scenarios including the effects of tax policies that subsidize or penalize fuels based on their relative greenhouse gas emissions (GHG), possible oil price shocks, and policies that target retail outlets.

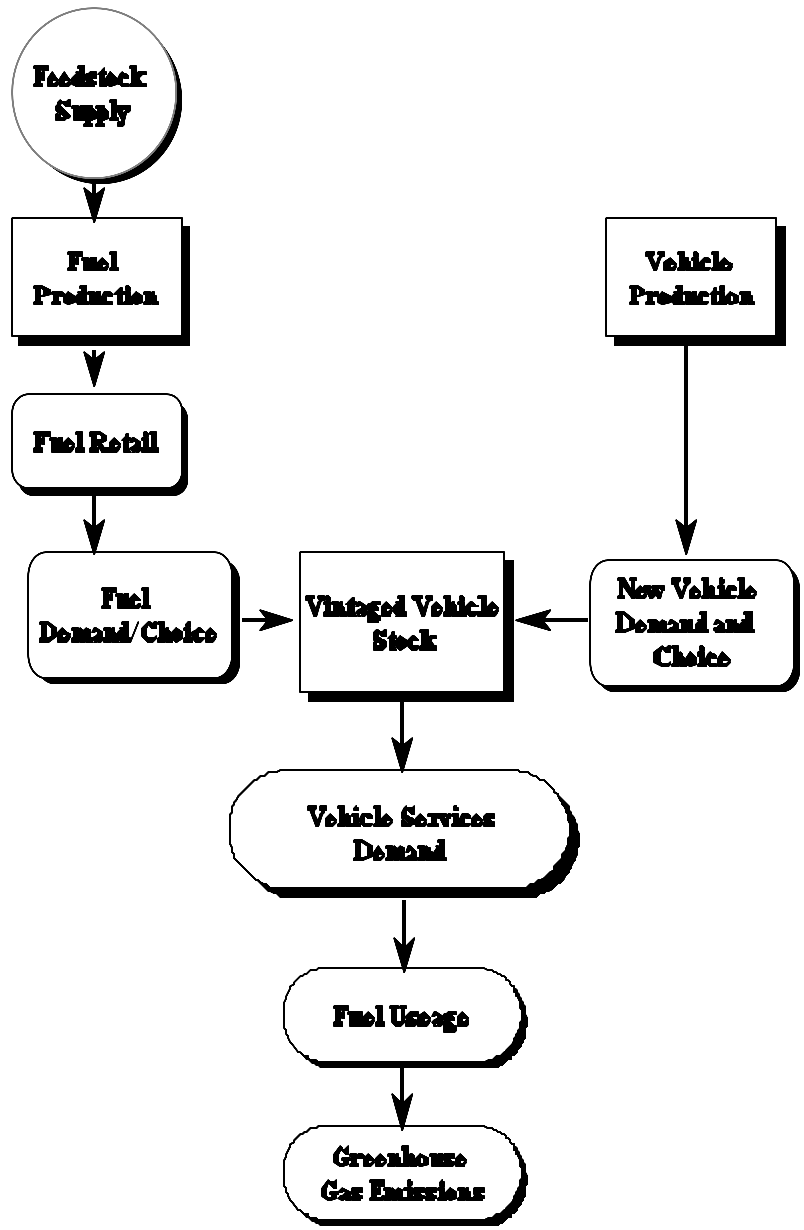
There are a variety of transitional phenomena at work in AFV markets, which might by influenced by policy. As alternative vehicle and fuel producers gain cumulative experience, some cost reductions through learning and economies of scale are expected. If vehicle manufacturers are encouraged to design and introduce new models with alternative fuel capability, the number of vehicle makes and models offering alternative fuel capability rises, and consumers value this greater choice. Incentives or programs leading to the earlier development of fuel distribution infrastructures can increase fuel availability. This can greatly lower the inconvenience cost associated with refueling, lowering the effective cost of alternative fuels. Promoting the introduction of AFVs may allow consumers to gain familiarity, reducing their uncertainty about fuel and vehicle performance and reliability. Programs calling for the purchase of AFVs by fleets induce vehicle production, promote refueling infrastructure, and lead eventually to the sale of used fleet vehicles to private consumers. The availability of AFVs to used-vehicle buyers, increases consumer familiarity with AFVs and alternative fuels, possibly leading to expanded private demand. Each of these possible linkages may work slowly, as investments are made and vehicle and capital stocks adjust. Many, but not all, of these transitional phenomena are captured by the current version of the TAFV model.

1.2 General Model Structure

The overall objective of the TAFV model is to maximize consumer and producer surplus (well-being) from transportation services. The TAFV model characterizes, in varying degrees of detail, interactions among fuel providers, vehicle producers, fuel retailers, private vehicle purchases and fleet vehicle operators. A schematic of these interactions is shown in Figure 2 below.[4]

[4]Further details on the general model structure can be found in Leiby and Rubin 1996, 1997.

Figure 2: Conceptual Diagram of TAFV Model



As is shown, new vehicles and vintaged on-road vehicle stocks are tracked. Also tracked are vehicle production capacities and utilization, fuel production, and fuel retail production and capacity. Within these modules are endogenous feedback effects from: vehicle economies of scale; the relative richness or "diversity" of vehicle models offered with each AFV technology; retail economies of scale; and, the cost to consumers of limited fuel availability.

1.3 Cost Function Representation of Supply Modules

Each of the supply modules shown in Figure 2 is represented by a single-period cost function C_{trf}, defined for each time period, region, fuel, and vehicle type. Examples include: vehicle production costs; fuel production or conversion costs; fuel retailing costs; raw material supply costs; and sharing or mix costs associated with vehicle and fuel choices. The sharing costs reflect the welfare loss due to the distortion of choice from the ideally preferred mix of fuel and vehicle non-price attributes, given unequal market prices of fuels and vehicles (Small and Rosen 1981, Anderson, de Palma and Thisse 1988, Leiby and Greene 1995). The cost functions summarize the way in which changing levels of activities, inputs, and outputs affect the costs for each supply module, and implicitly define the cost-minimizing behavioral relationships among the model's variables.

In some cases the supply module involves investments I_t in fixed capital stocks K_t with long-lived (multiperiod) costs and benefits. If so, the module cost function includes the net variable cost of current activities (C^v) *plus* the costs of current investments ($I_t\ C_t^K$) in each period minus the estimated discounted salvage value of all remaining capital stock at the end of the last period. Estimated salvage values are determined taking into account depreciation, discounting, and expected future use value. For vintaged vehicle stock, future use value declines with vehicle age and use.

1.4 Market Balancing Conditions

For each period, the objective is to represent the short-run market balance that results from maximizing consumer and producer surplus (well-being) from transportation services. This means that we wish to assure that the following short-run conditions are met in each period:

i. the marginal cost of producing each commodity equals its price;
ii. the marginal benefit of each demand equals its price;
iii. the marginal profitability of each intermediate conversion (e.g., converting gasoline and ethanol into E85) activity is zero (unless constrained, in which case short-run profits can be positive or negative); and,
iv. the marginal current period value of investment equals the price of capital minus the discounted expected future value of the equipment from the next period.

We require incremental investment in technology-specific capital to be non-negative. If new investment is zero, the profitability of existing capital is insufficient to motivate new investment, and the fourth condition stated above is not met. Disinvestment may be desired, but is not allowed.

The partial equilibrium solution is calculated with GAMS (Brooke, Kendrick and Meeraus 1992) and yields market clearing supplies, demands, trade, and conversion process levels. It requires that supplies, plus net output from conversion activities plus net trades between regions must be greater than or equal to demand. Final demands and basic commodity supplies are "price responsive" in that their quantities will depend on market prices in each period. Fuel blending and conversion, fuel distribution and retail markup, and the combination of fuels with vehicles to provide vehicle services are represented with linear conversion processes. For conversion processes requiring durable capital equipment (such as methanol fuel production or vehicle production), the maximum level of activity is constrained by the amount of installed capital. In addition, a capital stock evolution constraint links depreciated capital and investment in each period to the next period's starting capital stock.[5]

2.0 Principle Assumptions and Data

The important assumptions and data sources can be broken down into the following general areas.

- Wholesale fuel supply curves (annual) for
  - Gasoline
  - Natural gas (supply to transportation sector, net of other sector demands)
  - Ethanol (from corn and cellulosic biomass)
  - Foreign methanol
- Wholesale fuel conversion costs and input-output coefficients
  - LPG (based on natural gas price)
  - Methanol (from natural gas)
  - Electricity
- Vehicle production cost curves
- Motor fuels taxes
- Fuel distribution and retailing cost curves
- Greenhouse gas coefficients
- Fleet sales subject to AFV mandates (current and late rule)

Many, but not all, of these assumptions and data sources are described in the pages below.

2.1 Wholesale Fuel Supply Curves

Gasoline and Natural Gas

Annual wholesale gasoline and natural gas supply curves pass through the price and quantity projections from AEO98, taking into account price-quantity sensitivities as estimated by the AFTM. This methodology insures that the TAFV model uses the standard 1996-2010 AEO base price assumptions, but takes advantage of AFTM's extensive characterization of for the endogenous variation of price with quantity demand. These gasoline and natural gas supply curves can be seen in Figures 3 and 4.

[5]Technical details can be found in Leiby and Rubin (1997).

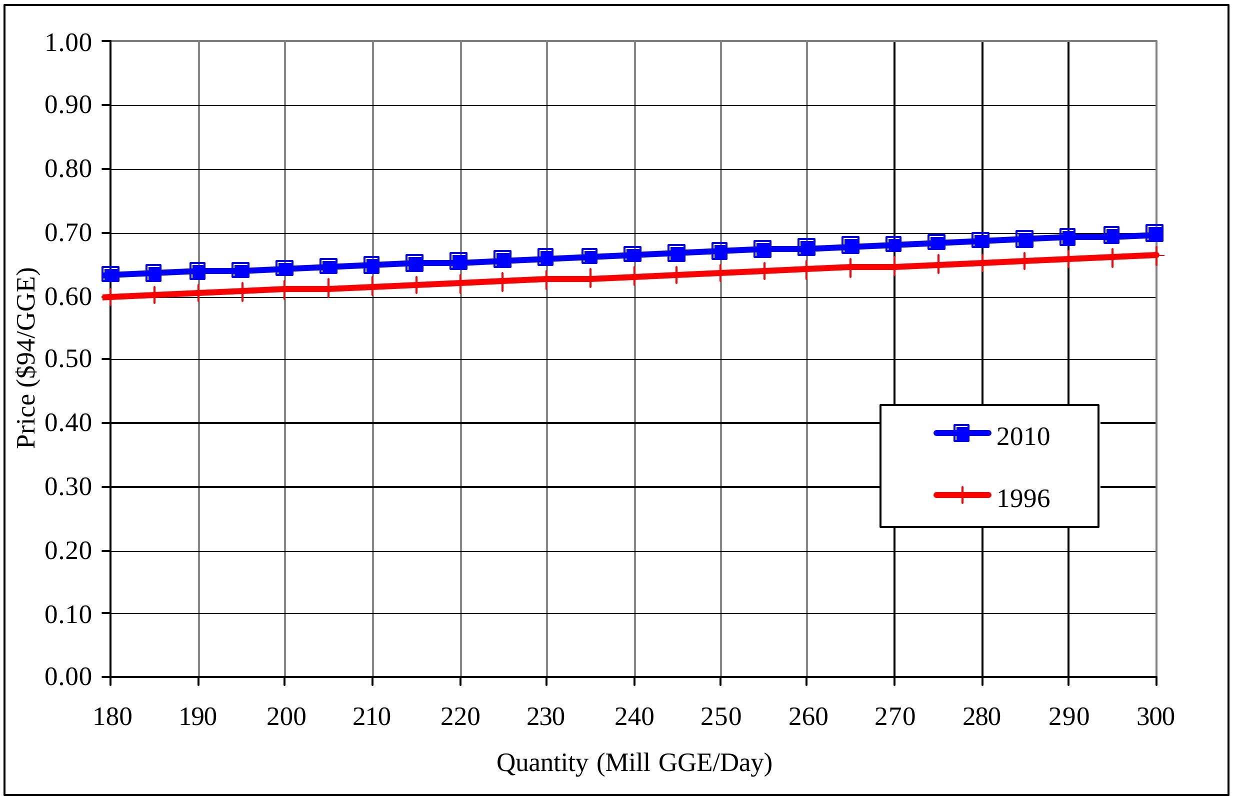


Figure 3: Gasoline Supply Curves

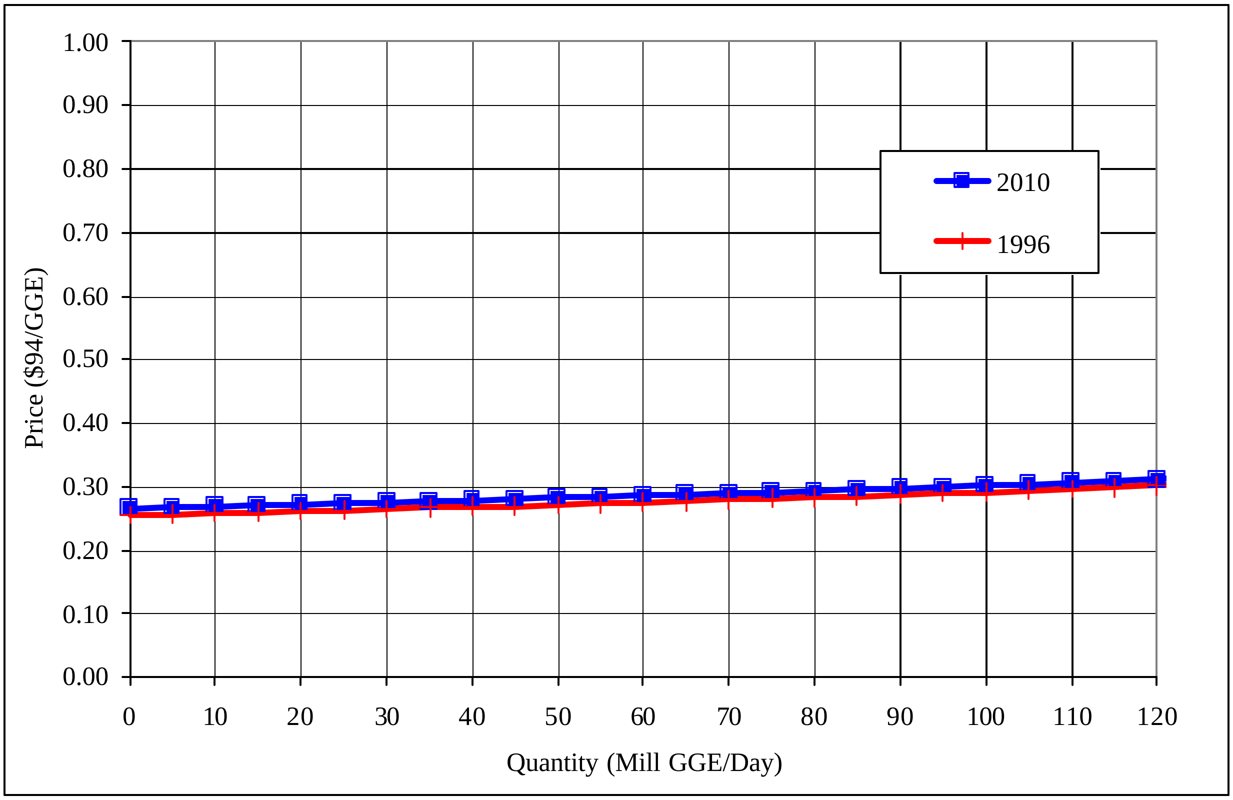


Figure 4: Plantgate Net Natural Gas Supply Curves for Motor Vehicles

Ethanol

Ethanol for use as either a neat fuel or additive can be efficiently derived from two primary sources: grains (corn) and woody biomass. Feedstock supply curves are derived from data provided by Walsh et al (1997), Perlack (1997), and Kimbill (1996). The feedstock supply and conversion process data were used to generate marginal cost curves for ethanol supply at five-year intervals. These aggregate biomass-to-ethanol supply curves reflect the least cost mix of the available biomass feedstocks. The aggregate supply curves were then fitted to a variable elastic functional form convenient for use in the TAFV model. These are shown in Figure 5, 6, 7 as the smooth fitted curves overlaying the more irregular estimated curves. Technical details on the construction of the ethanol supply curves can be found in Bowman and Leiby (1997).

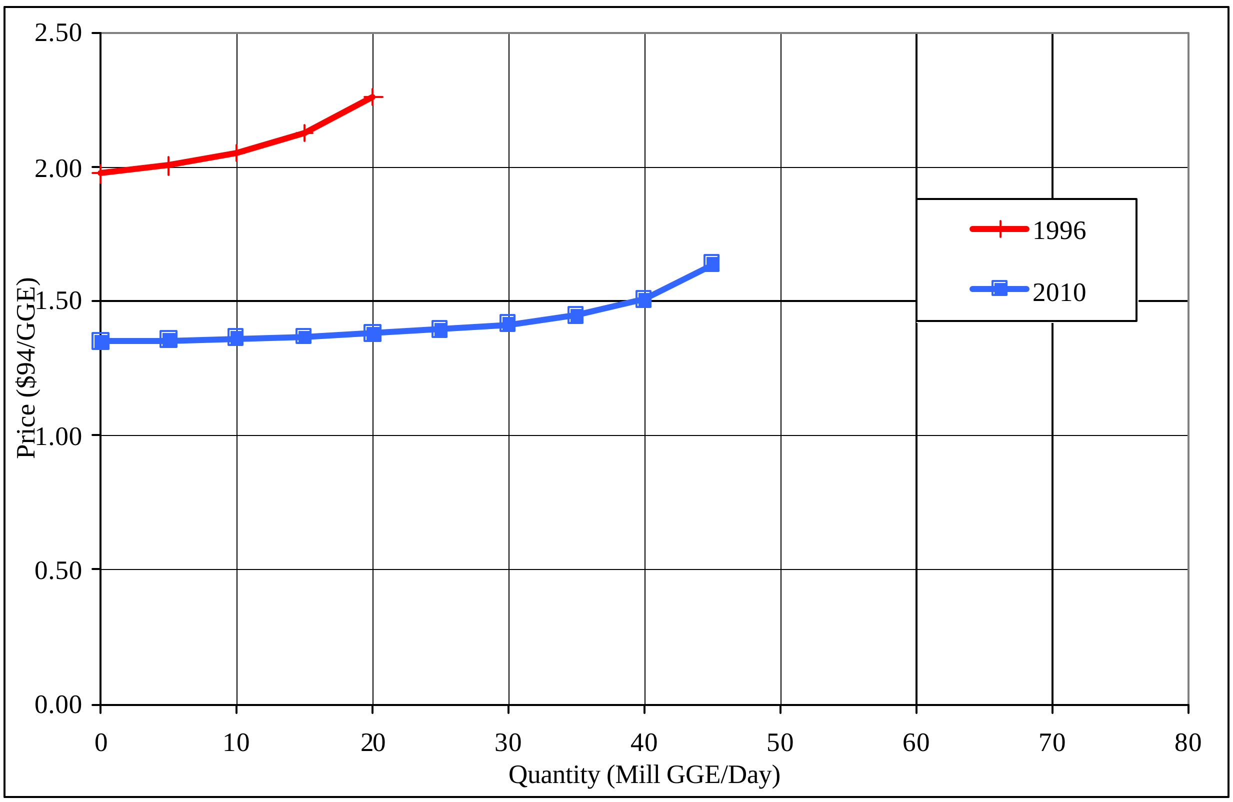


Figure 5: Plantgate Cellulosic Biomass to Ethanol Supply Curve

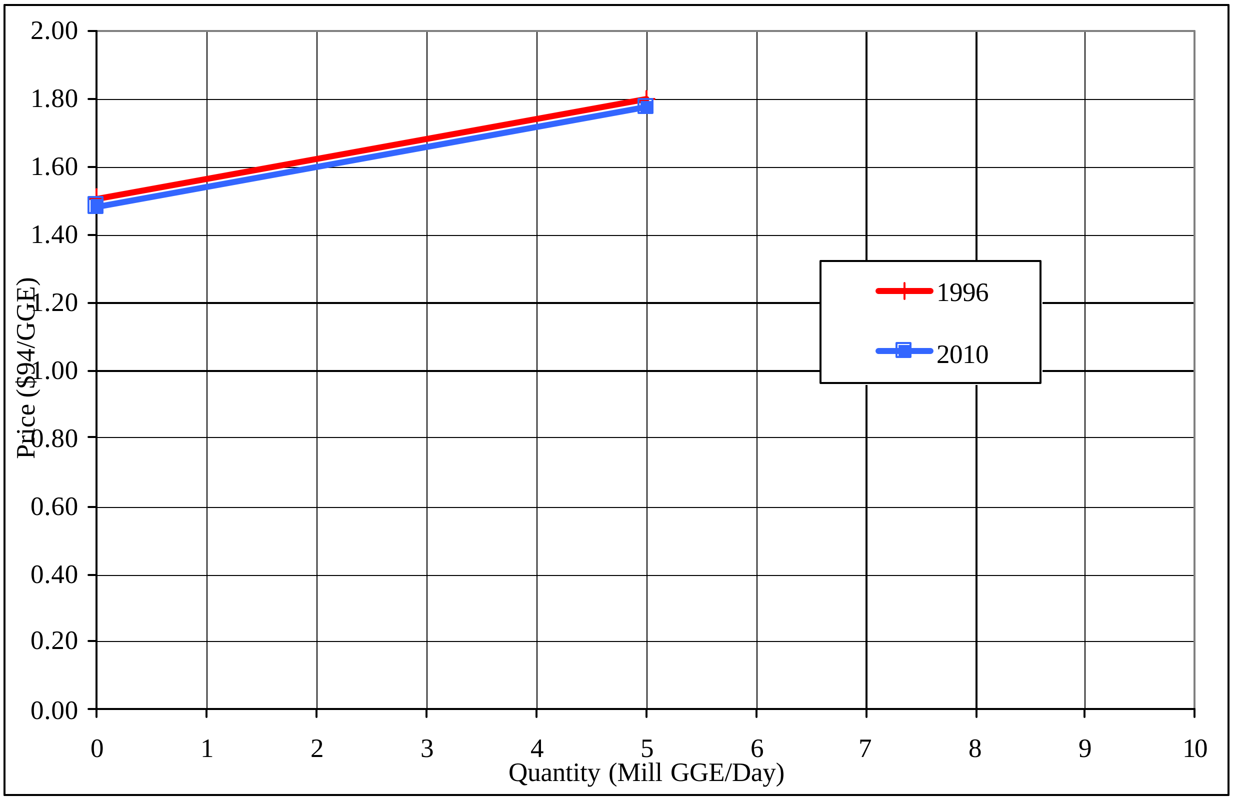


Figure 6: Plantgate Corn to Ethanol Supply Curve

Foreign Methanol

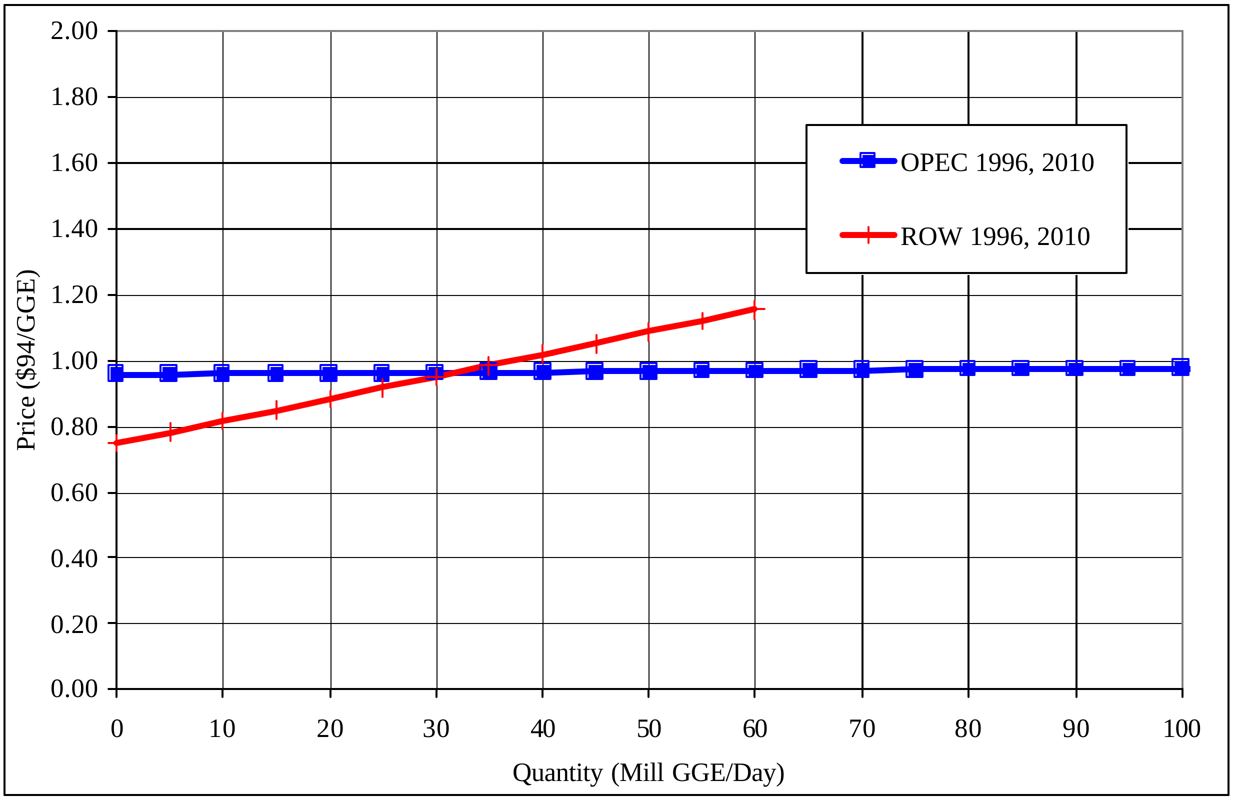


Figure 7: Foreign Methanol Ethanol Supply Curve

2.2 TAFV Motor Fuels Taxes

Taxes on gasoline and alternative fuels are a significant component of the overall cost of transportation services. Because fuel taxes are *not* equal on a per-mile or per-BTU basis, they can significantly alter the relative attractiveness of the transportation fuels. The base case results uses current federal tax rates (26 U.S.C. Sects. 4041, 4081) a weighted average of state excise taxes (USDOE, 1996, Table IV-1) and, for ethanol, a $0.54 per physical gallon ethanol tax credit.[6] These tax rates are shown below.

[6]Pursuant to TEA-21 the ethanol tax credit was extended through January 1, 2007 (TEA-21 Section 9003, "Extension and Modification of Tax Benefits for Alcohol Fuels."

Table 1: Fuel Taxes by Source				
Taxes per Physical Gallon				
Fuel	Federal[1]	State	Renewable Tax Credit	Total
LPG	0.14	0.14	0.00	0.27
M85	0.09	0.15	0.00	0.25
Gasoline	0.18	0.17	0.00	0.35
E85	0.18	0.15	-0.46	-0.13
CNG (per MCF)	0.49	1.24	0.00	1.72
Taxes per Gasoline Gallon Equivalent[2]				
Fuel	Federal	State	Renewable Tax Credit	Total
LPG	0.19	0.19	0.00	0.38
M85	0.16	0.27	0.00	0.43
Gasoline	0.18	0.17	0.00	0.35
E85	0.25	0.21	-0.64	-0.17
CNG	0.06	0.15	0.00	0.21

The base case price assumption maintains federal and state taxes constant in real value over the simulation time period. This assumption reflects the view that the majority of federal and state funds are dedicated to highway construction and maintenance and, therefore, will be periodically raised in nominal value to offset the effects of inflation. The ethanol tax credit is, however, not maintained at present value over the time horizon, but declines in value due to inflation assumed to be3%. A sensitivity case maintains the ethanol tax credit constant in real value.

2.3 Retail Fuel Supply Curves

Although all of the fuel costs (e.g., taxes, wholesale fuels costs, transportation and retailing costs) enter the model separately, retail fuel supply curves may be constructed to gain an aggregate view of the relative retail costs of the fuels to consumers. Since the price of each fuel depends on its level of use, each retail supply curve shown below is based on the assumption that all other fuels are held constant at their equilibrium levels. Plantgate fuel prices are baselined to AEO98 projections for 1996 and 2010. Distribution costs, retail markups, and taxes are from various other sources. At the plantgate level, the price of E85 from biomass does become cheaper by 2010 due to expected technological advances in biomass conversion efficiencies. Over this same time period, however, the $0.54 per gallon tax credit is scheduled to be phased out and the two effects offset. Were this tax credit not phased out (as is assumed in one policy case discussed below) the retail price of E85 would be much cheaper than that shown below for 2010.

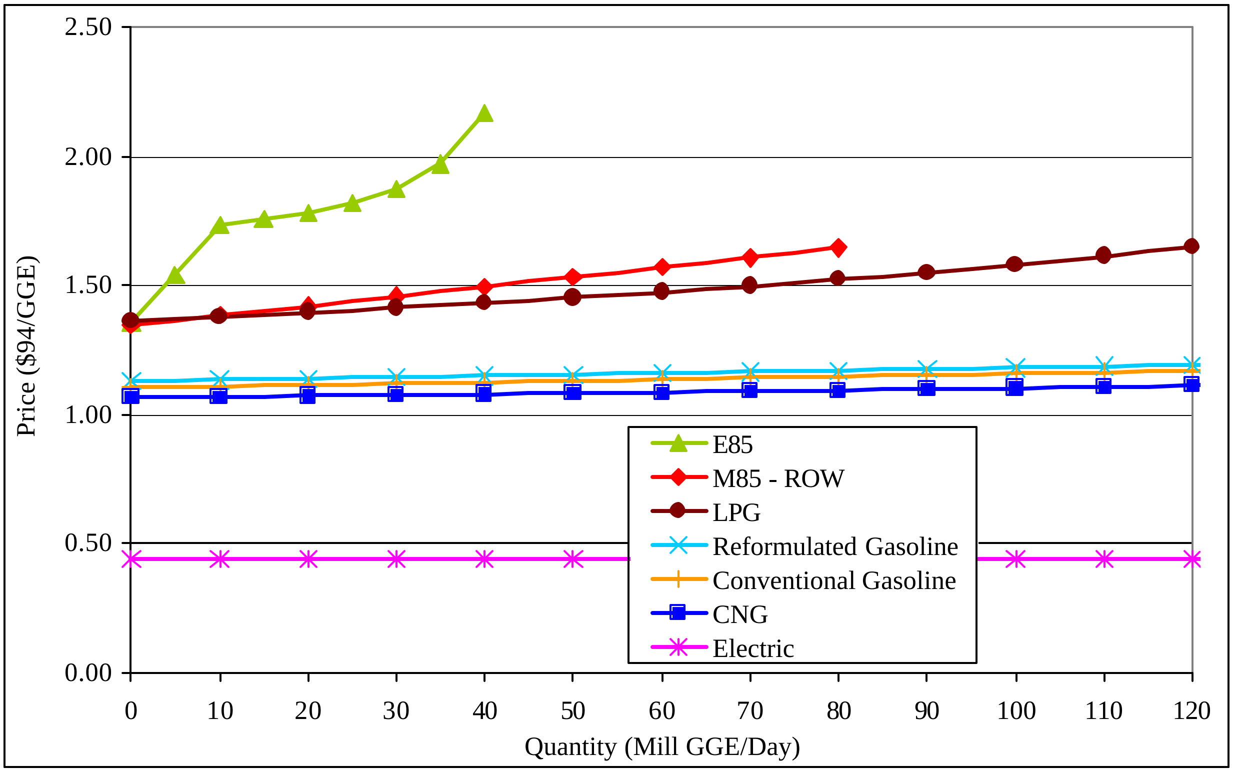


Figure 8: 1996 Retail Fuel Supply Curves

Note: Legend order follows magnitude in price. Prices for Conventional Gasoline shown at the 150-270 Mill GGE/Day, all others 0-120 Mill GGE/Day.

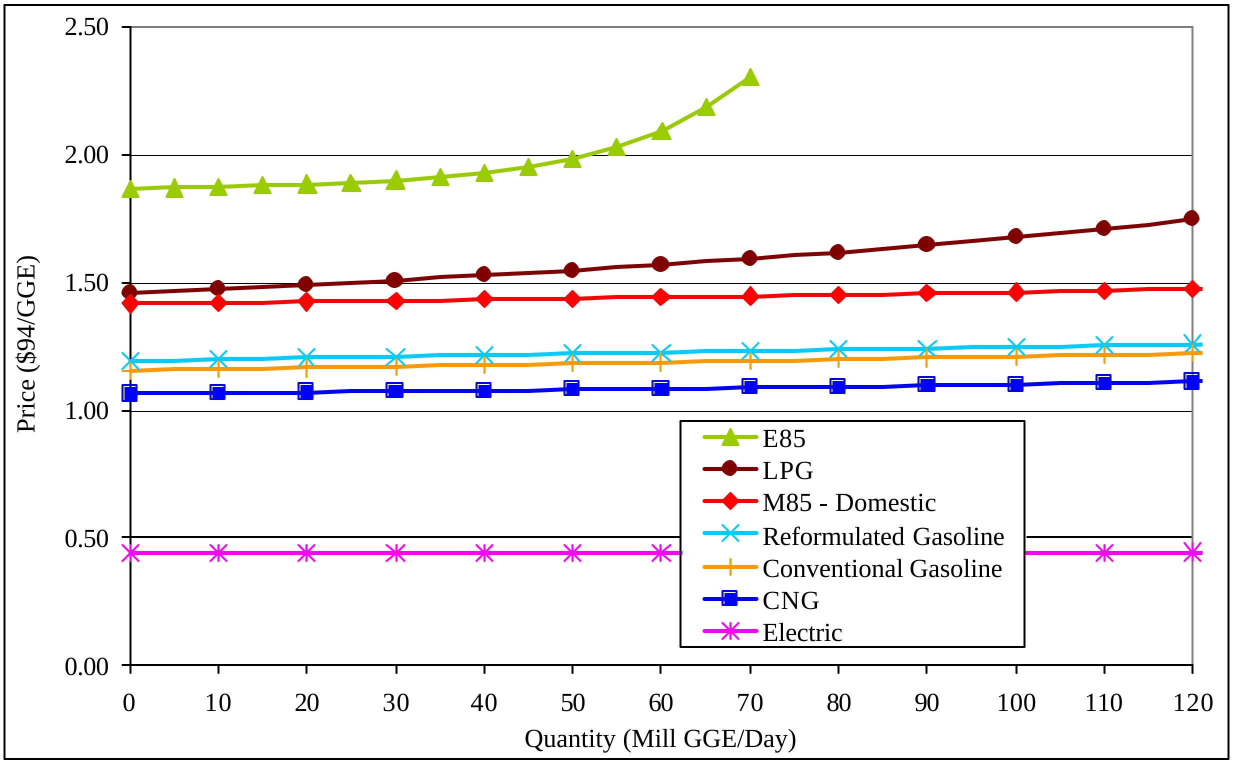


Figure 9: 2010 Retail Fuel Supply Curves

Note: Legend order follows magnitude in price. Prices for Conventional Gasoline shown at the 150-270 Mill GGE/Day, all others 0-120 Mill GGE/Day.

2.4 Vehicle Services Demand for New and Used Vehicles

Benefits in this model come from the satisfaction of final demand for transportation services. Reference final demand is determined from projections of light-duty vehicle fuel use (excluding diesel) from VMT projections for 1996 to 2010 given in the AE098. The total demand for light-duty fuel is satisfied by the use of existing (used) vehicles and the purchase and use of new vehicles. The use of older vehicles is limited by the stock of each vehicle type given a fixed, age-adjusted use profile.

Each year, to the extent that existing vehicle stocks are insufficient to satisfy the demand for transportation services, a mix of new vehicles is purchased. New vehicles are chosen according to a nested multinomial logit (NMNL) choice formulation, which is a common way of modeling discrete choice behavior. Vehicle choice is based on up-front vehicle capital costs, non-price vehicle attributes and expected lifetime fuel costs. In this way, long-lived investment consequences are reflected in vehicle choice. Nested fuel choices must be made for the vehicles that are dual or flexibly-fueled, based on fuel price and non-price attributes.

Formally, for composite vehicle services demand in year t of type g, the choice fraction for input alternative f will depend upon its (conditional expected indirect) utility, V_{tgf}, which is a linear function of new vehicle price P_{tf} and non-price attributes:

$$V_{tgf} = \beta_g \left(P_{tf} + \alpha_{fR} + \alpha_{fW} + \alpha_{fD} + \frac{\beta}{\beta_g} C_{gf}\right) \quad \textbf{(1)}$$

The attributes include, for example:

- β_g — cost sensitivity parameter for choice over vehicle types;
- P_{tf} — vehicle price for fuel technology f, at time t;
- α_{fR} — vehicle range (distance between refuelings) equivalent cost;
- α_{fW} — vehicle weight to performance equivalent cost;
- α_{fD} — relative diversity of vehicle models, equivalent cost;
- β — fuel price sensitivity for vehicle; and
- C_{gf} — expected effective fuel cost over vehicle's lifetime, given current and expected future prices for the fuels vehicle f may use, and accounting for expected fuel availability, and other fuel attributes.

The choice among vehicles, therefore, responds to endogenous current vehicle and fuel prices and endogenous future fuel prices. The treatment of vehicle and fuel choice parameters in the TAFV model is based on Greene's "Alternative Vehicle and Fuel Choice Model," (Greene, 1994).

Since vehicle and fuel choice is endogenous, it is important to specify which fuel and vehicle characteristics are considered in the fuel and vehicle choice sub-modules, and which characteristics are endogenously determined. These characteristics are shown in the Table 2.

Table 2: Factors Influencing Fuel and Vehicle Choice		
Factors considered in Fuel Choice	**Endogenous**	**Exogenous**
Fuel Price	X	
Fuel Availability (fraction stations offering fuel)	X	
Refueling Frequency (based on range)		X
Refueling Time Cost		X
Performance Using Fuel (HP:weight ratio changes)		X
Factors Considered in Vehicle Choice	**Endogenous**	**Exogenous**
Vehicle Price	X	
Fuel Cost (including effective cost of non-price fuel attributes)	X	
Performance (changes in HP-to-weight ratios)		X
Cargo Space (loss due to space required for fuel storage)		X
Vehicle Diversity (number of models offering AFV technology)	X	

Given the exogenous vehicle and fuel characteristics shown above, Table 3 gives the default shares of fuels and vehicles if their endogenous prices and availability were equal. The TAFV's projected fuel and vehicle choices differ from these default shares to the extent that all fuels and vehicles do not have equal prices and availability.

Table 3: Market Choice Shares Given Equal Prices, Fuel Availability and Vehicle Diversity			
Vehicle	**Fuels**	**Fuel Share**	**Vehicle Share**
Conventional	Conventional Gasoline		16.9%
	Conventional Gasoline	19.0%	
	M85	40.20%	
Flex-Fuel	E85	40.20%	16.8%
	Conventional Gasoline	90.8%	
CNG Bifuel	CNG	9.2%	7.1%
	Conventional Gasoline	76.0%	
LPG Bifuel	LPG	24.0%	13.8%
CNG Dedicated	CNG		9.7%
LPG Dedicated	LPG		15.6%
	M85	50.0%	
Alcohol Dedicated.	E85	50.0%	19.4%
Electric	Battery EV	0.0%	0.6%
Total	NA	NA	100.0%

2.5 Key Transitional Phenomena Modeled

From preliminary analysis, and discussions with our working group, we have identified some key areas that strongly affect the transition to alternative fuels and vehicles. Because of their potential importance, these areas have been explicitly modeled.

- Costs to consumers of limited retail fuel availability for alternative fuels

- Capital stock durability and turnover
  - Vintaged vehicles
  - Durable vehicle and fuel production plants (for domestic methanol)
  - Durable retail fuel infrastructure
- Scale economies for vehicles and fuels

- Endogenous vehicle model diversity
    - costs to producers
    - value to consumers

2.6 Effective Costs of Limited Retail Fuel Availability

Most alternative fuels are currently available at only very few retail stations. First principles, and evidence from surveys of diesel car buyers (Sperling and Kurani, 1987) suggest that fuel availabilities below 10% can impose large implicit costs on consumers. There is, however, little empirical evidence as to the possible size of these costs. Our approach is to use work by Greene (1997) who models availability using a random utility, binomial logit choice framework. Within this framework, the value, or utility, that the *j*th individual receives from choosing fuel option *i* is given by

$$U_{ij} = A_i + B \cdot P_i + C \cdot g(\sigma_i^R) + \varepsilon_{ij} \qquad \textbf{(2)}$$

where A_i are non-price attributes of the fuel (e.g., safety, smell, etc.), P_i is the price of the fuel, $g(\sigma_i^R)$ is the perceived retail availability of the *i*th fuel and ε_{ij} is a random error term. The term *B* converts the market price of fuels in to consumer satisfaction or utility and, hence, can be interpreted as the marginal utility of a dollar. The log of the odds in favor of purchasing fuel option 2 rather than fuel option 1 is given as[7]

$$\ln\left(\frac{Prob_2}{Prob_1}\right) = A_2 - A_1 + B(P_2 - P_1) + C(g(\sigma_2) - g(\sigma_1)). \qquad \textbf{(3)}$$

To determine what percentage of the time consumers would choose to use one fuel rather than another given different fuel prices and availabilities, Greene asked the following question in two national surveys:

> "Suppose your car could use gasoline or a new fuel that worked just as well as gasoline. If the new fuel costs 25 (10, 5) cents LESS per gallon but was sold at just one in 50 (20, 5) stations, what percent of the time would you buy this new fuel?"

The results from these surveys were used to estimate **(3)**. In order to do the estimation, a functional form must be chosen for $g(\sigma)$. Greene estimated four forms: linear ($g(\sigma) = \sigma$), exponential ($g(\sigma) = e^{b\sigma}$), power ($g(\sigma) = \sigma^{b}$), and logarithmic ($g(\sigma) = \ln(\sigma)$). The costs per gallon for limited fuel availability using the two better-fitting functional forms are shown in Figure 10.

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[7]This result follows from making the standard assumption that the error term follows a type 1 extreme value distribution, see Madalla, Chapter 2.

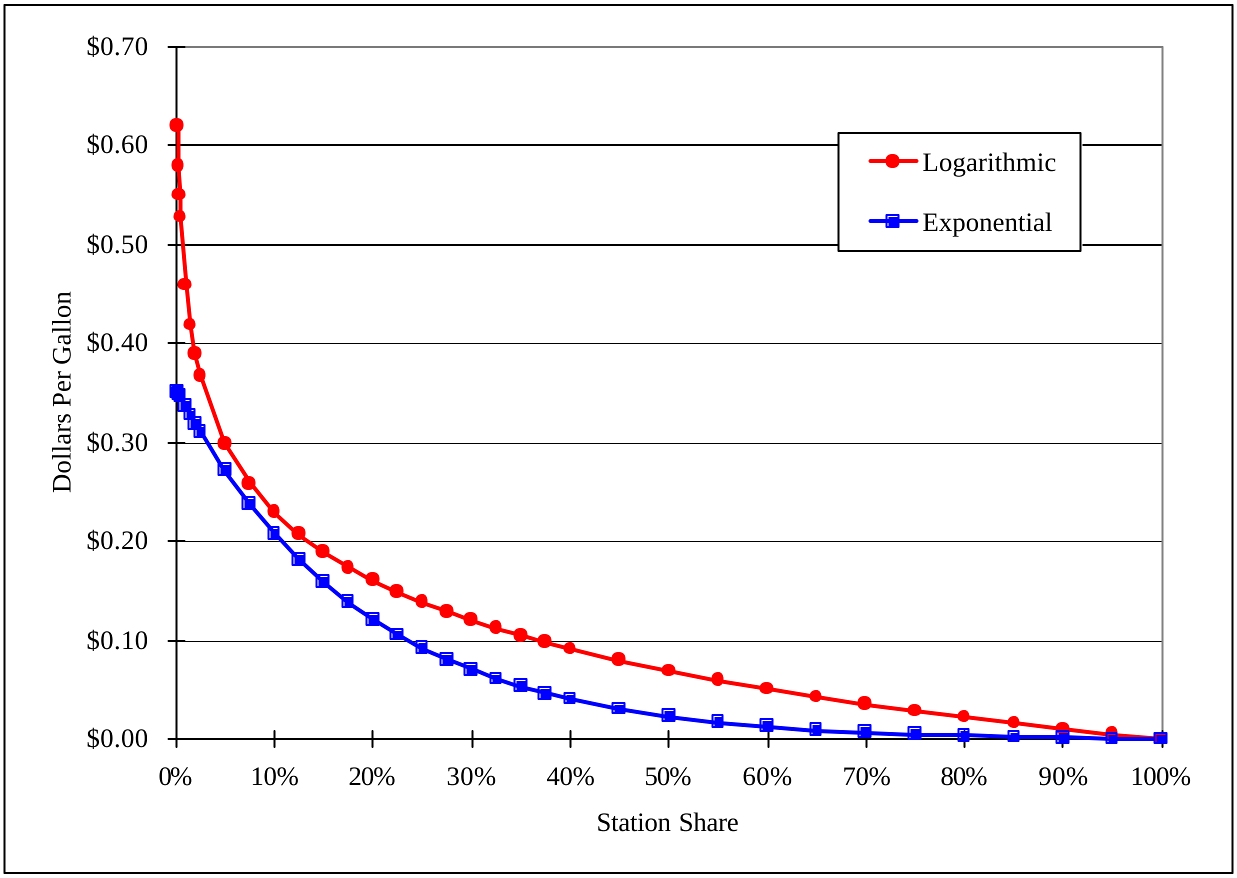

Figure 10: Costs of Limited Retail Availability

Greene notes (p. 34) that it is not possible to definitively discriminate among the alternative functional forms, but that the exponential functional form fits the data best and behaves reasonably over the whole range of fuel availabilities. Besides issues of fit, we have chosen to use the exponential functional form because our intuition tells us that at 50% fuel availability (every other gas station) the cost penalty ought to be small. For the exponential functional form, the cost penalty at 50% availability is 2¢ per gallon, while the fuel availability cost is 7¢ per gallon using the logarithmic functional form. At 0.1% fuel availability the cost per gallon, using the exponential functional form, is 35¢.

2.7 Vehicle Manufacturers' Costs per Model

The TAFV model is designed to estimate the costs of vehicle production for the following alternative fuels: LPG, CNG, alcohols, and electricity. The vehicles are either dedicated to a particular fuel type or are capable of using both gasoline and the respective alternative fuel.[8] AFV costs (shown in Table

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[8]The one exception is electricity. Hybrid electric vehicles are currently not characterized in the model, but we plan to include them in the future.

4) are calculated from engineering-economic estimates of the incremental cost of each AFV fuel technology compared to conventional vehicle technology (EEA, 1995c). EEA believes that AFV technologies, except for electric vehicles, are mature. Here "mature" means that, for a given production scale, further production experience will not reduce per-unit production costs at a rate significantly faster than conventional vehicle production costs will decline. There do exist, however, substantial per-unit cost savings with larger scale production.

We therefore model per-unit vehicle production costs as a declining function of the installed production capacity available in each year. The volume of production in any given year is constrained by the level of cumulative capacity investment less capacity decay. This means that vehicle prices are endogenous variables. This has the advantage of admitting the positive feedback effects from policies (such as AFV fleet programs) that encourage the adoption (and hence larger scale production) of AFVs.

Table 4: Incremental Vehicle Production Costs
(Capital and Variable, Compared to a Gasoline Vehicle)*

Vehicle Type	**Plant Scale (Vehicles per Year)**		
	2,500	25,000	100,000
Alcohol Dedicated	$2,038	$363	$223
Alcohol Flexible	$1,911	$409	$284
CNG Dedicated	$5,349	$1,841	$1,548
CNG Dual	$5,792	$2,015	$1,701
LPG Dedicated	$3,745	$972	$741
LPG Dual	$3,778	$1,109	$887
Electric Dedicated (1996)	$42,125	$11,060	$8,471
Electric Dedicated (2010)	$29,627	$5,974	$4,003

*For large passenger vehicles. Note: these figures reproduce the estimated IRE based on EEA's accounting methodology, "Specification of a Vehicle Supply Model for TAFVM," Sept., 1995, p.1-2. They differ slightly from some numbers in EEA's Table 5-2.

For each fuel technology, vehicle costs increase as the richness of offerings (the number of makes and models) increases. Vehicle diversity is a choice variable under the control of the vehicle producer. Note that while model diversity adds to the vehicle producers' costs, there is a motivation for producing diversity since it makes a vehicle (fuel) type more attractive to consumers. Representative cost curves for these vehicle types are shown in Figure 11.

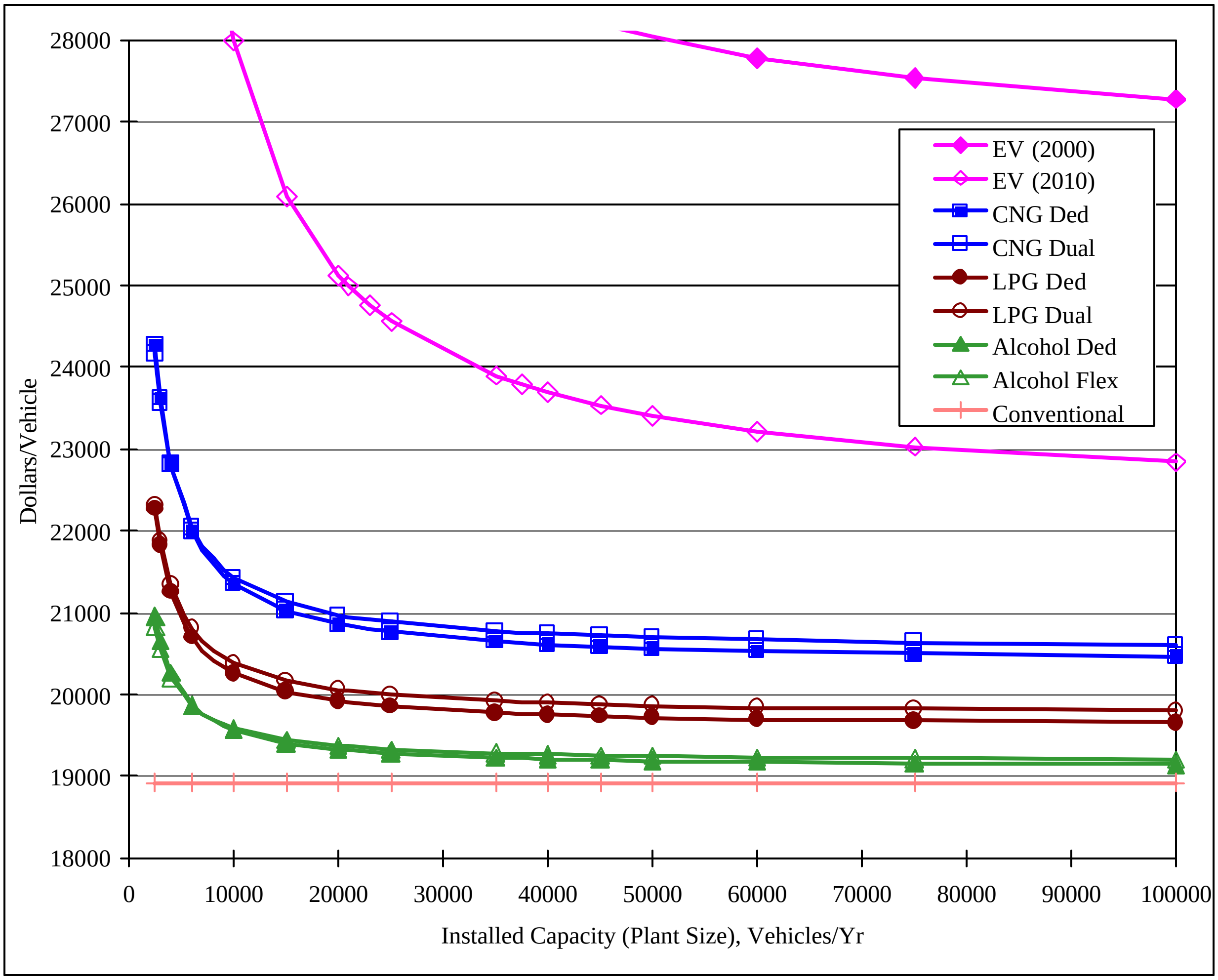

Figure 11: Vehicle Production Cost vs. Scale

2.8 Endogenous Vehicle-Model Diversity and the Effective Cost of Limited Diversity

Consumers contemplating buying a new gasoline-fueled car are offered a wide variety of makes and models with a huge number of features to choose among. The attractiveness of an alternative fuel technology will depend on the diversity of vehicle models for which it is available. Offering, for example, methanol fuel technology on only a single model will put methanol vehicles at an disadvantage compared to gasoline vehicles, all else equal. At the same time, offering methanol capability on several different models is expensive because it lowers plant scale for any overall level of production. Rather than predetermining the number of makes and models offered with alternative fuel capability, we endogenize the level of model diversity by balancing the additional production costs off against the additional consumer satisfaction.

This is accomplished by defining a variable n_f which represents the number of makes and models of fuel type f produced. On the vehicle production side we divide the total industry production capacity for vehicles of fuel type f by n_f to determine the average plant size. On the consumer side we incorporate n_f into the our multinomial choice framework by adapting a framework suggested by Greene (1997). In our approach, the unit consumer benefit of having n_f models to choose from with fuel type f, is:

$$B_f = \frac{\alpha}{\beta} \ln\left(\frac{n_f}{n_1}\right) \qquad \textbf{(4)}$$

where:

n_1	number of conventional gasoline vehicle models offered, based on current data;
β	NMNL parameter for choice among vehicle-types; and
α	reflects the popularity-order in which manufacturers choose vehicle models to offer the fuel technology f.

If alternative fuel capability is introduced "randomly" on different vehicle models, then the appropriate value for α is $\alpha = 1$. On the other hand, if the new technology is offered on the most popular vehicles first, then we can estimate α based on the current popularity distribution of conventional vehicle models ($\alpha \approx 0.37$). Numerically, this implies that the unit costs of limited diversity per AFV would range over the following magnitudes:

$0/vehicle (when model diversity matches that of conventional vehicles);
$770/vehicle (if the new fuel technology is offered on the most popular models first), and
$2080/vehicle (if fuel technology is offered on only one random model AFV).

In the simulation results shown below we have assumed that AFV technology would be introduced on the most popular models first. Therefore, the realized cost of model diversity will vary between $0 and $770 depending on the number of models offered. The number of AFV models built will be determined by the market tradeoff between production costs and the additional consumer satisfaction gained from the greater model diversity.

2.9 Gasoline Displacement by Replacement Fuels in Reformulated and Oxygenated Gasoline

Some gasoline is displaced by replacement fuels embodied in reformulated and oxygenated gasoline which contain natural gas, hydrogen, and alcohol and ether oxygenates. For this analysis the assumed average oxygen content of the pool of reformulated gasoline is 2.2 percent by weight. The fraction of reformulated gasoline assumed to exist over the entire time horizon is set at the 1997 level of 31.2%. Oxygenated gasolines make up an additional 7.3% of total motor fuel demand or 10.75 % of the conventional and oxygenated mix (EIA, 1997, Table 2).

Table 5: Replacement Fuel Coefficients	
Fuel	**Replacement Coefficient**
Conventional Gasoline	6.52%
Reformulated Gasoline	14.39%
M85	75.37%
E85	80.39%
CNG	100.00%
LPG	100.00%
Electricity	100.00%
Gasohol	11.82%

3.0 Scenarios and Results

The TAFV modeling study has been designed to examine the possible transition from the current market in which there is relatively little alternative fuel use to one in which alternative fuels replace a substantial fraction of gasoline, such as the outcome characterized by DOE's earlier long-run analysis (AFTM, USDOE 1996). The distinguishing feature of this current AFV study is its attention to transitional barriers to the introduction of alternative fuels and vehicles. Transitional barriers include: vehicle and fuel production scale economies; the consumer costs of low retail fuel availability and limited AFV vehicle model diversity; and the slow turnover of durable capital equipment and vintaged vehicle stock. These transitional barriers may delay or even prevent the adoption of alternative fuels. Given dynamic effects, positively reinforcing fuel and vehicle technologies, and transitional issues, the market may either not attain a new steady-state equilibrium, or it may find some new equilibrium distinct from both the current gasoline-based light-duty vehicle economy and from the long-run alternative fuel mix indicated by prior single-period analyses.

To assess the importance of transitional barriers, our first two scenarios examine the model's implications for alternative fuel use in the absence of any new policies, without and with the inclusion of potential transitional barriers. The "base" case scenario uses the TAFV model as constructed, including transitional barriers, and assumes no new policy initiatives by the federal or state governments. The "no transitional barriers" scenario uses the TAFV model with base policy assumptions, but eliminates all transitional barriers, in order to compare its behavior to DOE's previous long-run equilibrium analyses (e.g. AFTM, USDOE 1996). Subsequently, we discuss many of the 23 policy combinations considered to examine a wide range of potential federal policies such as: the impact of a federal rulemaking to require private and local government fleets to purchase AFVs, fuel tax subsidies, various versions of the Ensign Bill, and the mandated sale of alternative fuels. A complete list of the policies, and assumptions behind the scenarios, can be found in Appendix 1.

Table 6: Fuel Cost and Tax Scenarios	
Name	**Description**
Base Case	AEO98 Base Case Fuel Prices
High Oil Price	AEO98 High World Oil Price projection (including higher gas prices)
Favorable	AEO98 High World Oil Prices with tax credits inflation adjusted
Lower LPG, Cost	AEO98 Base Case Fuel Prices with lower LPG prices
Lower LPG, High Oil Price	AEO98 High World Oil Prices with lower LPG prices
Oil Shock	AEO98 Base Case Fuel Prices with an oil shock in 2005

Each of the policy cases is run under the six different fuel price and tax scenarios shown in Table 6. In total, therefore, there are 138 policy cases (6 X 23). Since it is not practical to present this much material in tabular form, we can provide software upon request for readers interested in the detailed results not summarized in this section. Instructions on how to use this software are found in Appendix 3, 4.

3.1 Base Case Scenario Assumptions

In the TAFV model analyses, fuel production costs vary over time. In the base case and elsewhere, unless specifically noted, reference costs reflect AEO98 projections as described in Section 2. Alternative fuel taxes reflect current law, with a phase-out of the ethanol incentive by 2008.[9] There are two federal AFV policies currently in place which we model explicitly: EPACT's existing mandated purchases of AFVs by fleets, and CAFE credits for producers of AFVs. Both the existing EPACT fleet mandates and possible additional fleet mandates which may be required under a "private and local rulemaking" are shown in Figure 12. As is seen, these fleet vehicle mandates currently represent less than one-half of one percent of new vehicle sales. Under the Private and Local Rule, fleet vehicle purchases rise to about two and a quarter percent of new vehicle sales.

[9]We have chosen to use motor fuel taxes denominated in constant, rather than current, dollars. This reflects the anticipated rise in nominal fuel taxes to maintain the current level of funding for the highway trust fund. In contrast, the ethanol tax credit is denominated in nominal dollars and declines at a 3% a year reflecting our assumption about the long-term rate of inflation.

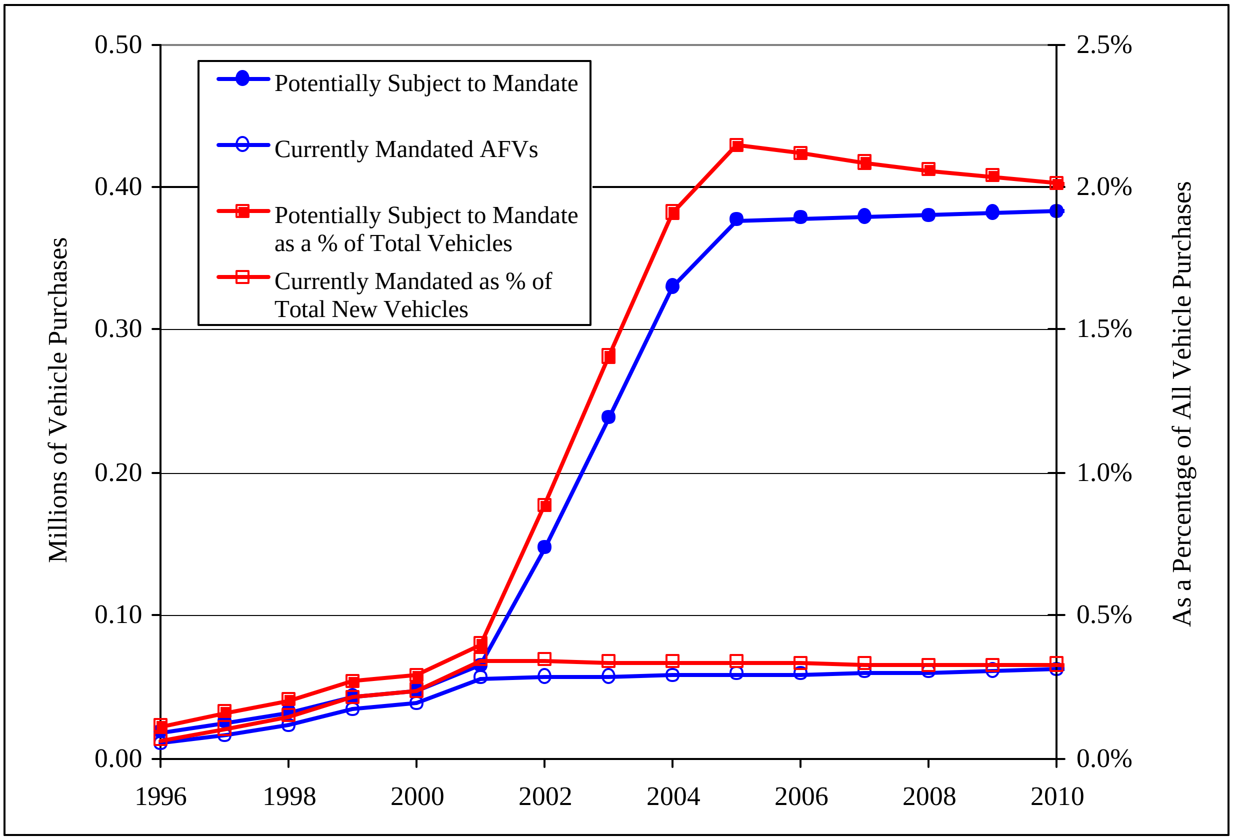

Figure 12: EPACT Mandated Fleet Purchases

A second important policy driver included in the base case is the favorable treatment received by AFVs in the calculation of each manufacturer's Corporate Average Fuel Economy (CAFE). When calculating a vehicle manufacturer's CAFE under the provisions of the Alternative Motor Fuels Act of 1988 (AMFA), AFVs are treated as highly fuel-efficient. This makes it easier for a manufacturer to comply with the CAFE standards. According to the AMFA (including revisions contained in EPACT), a gallon of alternative fuel used in a dedicated alternative fuel vehicle shall be considered to contain 15% of a gallon of gasoline (on an equivalent fuel basis). Based on avoided penalties, our analysis indicates that CAFE credits are worth $686 for dedicated vehicles and $343 per vehicle for flexible (and bifuel) vehicles (Rubin and Leiby, 2000). Dedicated and flexible vehicles can accumulate credits up until new vehicles sales reach 0.5% and 1.0% respectively in each year. Beyond that point the CAFE standards are unlikely to be binding, and therefore the value of any additional credits would be eliminated. In addition, following the AMFA, CAFE credits for FFVs and dual-fuel AFVs are discontinued after 2005.[10]

[10]The AMFA, Section 513(g), also limits the maximum increase in a manufacturer's average fuel economy attributable to dual and flexible fueled vehicles to 1.2 MPG. No limit is placed on the CAFE MPG increase due solely to dedicated AFVs.

3.2 Base Case Fuel Prices with No Transitional Barriers

The no transitional barriers (long-run analysis) case considers what the evolution of alternative fuels would be if there were no transitional barriers: if vehicles and fuels were produced at large scale costs, all motor fuels were widely available at retail locations, and the limited diversity of AFV models were not an issue.[11] Given AEO98 base case price assumptions, this scenario shows show a 7.7% alternative fuel penetration by 2010 even in the absence of any new policies. This result uses revised LPG costs that are higher than those assumed in the AFTM long run analysis (USDOE, 1996). In addition, AFVs represent 32% of newly purchased vehicles. Using the lower LPG costs and higher world oil prices (similar to those used in the AFTM) shows about a 20% 2010 penetration of alternative fuel with new AFVs making up about 53% of new vehicles. These results and others are displayed in Table 7, 8, 9, 10, 11, 12.

In the no transitional barriers case using base case fuel prices, by 2010 a total of 15% of gasoline is displaced with neat alternative fuel and oxygenate blends. Other fuel price assumptions increase this displacement level. With high world oil prices, petroleum displacement rises to 18% by 2010. If lower LPG costs are also available, then in the absence of transitional barriers, we find that petroleum displacement would be 25.5%. These results are quite similar to those achieved in the long-run static market penetration analyses done previously with the AFTM model, which found that EPACT's 30% gasoline displacement goal could be achieved.

3.3 Base Case Fuel Prices with Transitional Barriers

This case characterizes the possible market evolution starting from the current limited alternative fuel availability and low AFV production scale, with no new policy. In the base policy case there is almost no use of alternative fuels (less than ½ %) and very little production of AFVs (about 1%), *regardless of the assumed fuel and tax scenario*. These results seem in marked contrast to DOE's 1996 long-run analysis, which concluded that if the necessary infrastructure for a mature alternative fuel and vehicle industry were present, then "alternative fuels, as a group, appear likely to sustain a 30-percent market share under equilibrium conditions." (DOE 1996:13). However, the modeling results here suggest that the necessary infrastructure may *not* evolve smoothly, and fuel and vehicle prices may not benefit from economies of scale in the absence of additional policies. Therefore, gasoline displacement may be very

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[11] One way in which the "no transitional barriers" case above is distinguished from the AFTM long-run analysis for 2010 is that the TAFV explicitly limits annual increases in AFV penetration by the rate of vehicle scrappage, and by maximum expansion rates for the production of some vehicle types. Another issues is that at present in the TAFV model has less international detail. For example, TAFV includes foreign methanol production, but not foreign LPG productions, while the AFTM analysis indicated that by 2010 some of the LPG used would be imported. Another modest difference is the treatment of retail fuel availability. In the AFTM, all fuels are assumed to be widely available. In the TAFV no transitional barriers case we assume that there is no consumer cost to low availability. The least-cost way of providing fuels under this assumption is to have the retailing of each fuel be concentrated in a limited number of stations, achieving scale economies in station operations for each fuel. This does have some small effect on the retailing cost.

limited.

This is an important finding. It shows the crucial need to recognize transitional barriers when examining new, emerging technologies. Static, long-run equilibrium analyses ("snapshots") are likely to lead to misleading results when technologies and infrastructures are evolving.

CAFE-AFV Interactions

Although the base case results show little in the way of alternative fuel and vehicle use, they are still worth examining in greater detail. Interestingly, after an initial start up period of two years, the combined AFV sales (under all price and tax scenarios) are just under 1% of vehicle purchases, with the majority of the vehicles being alcohol FFVs. This result comes from the subsidies received due to favorable AFV treatment under CAFE regulations.

Fuel Displacement

As discussed above (in Section 2.9), petroleum is displaced from use in the light-duty vehicle sector from the use of alternative fuels as well as through the use of reformulated and oxygenated gasoline containing natural gas, hydrogen, and alcohol and other oxygenates. Thus, the quantity of petroleum displaced will always be greater than the quantity of (energy adjusted) alternative fuel used. In the base case, 9.1% and 9.2% of petroleum is displaced in the years 2000 and 2010, respectively. The quantity displaced is virtually the same in both years because the is very little alternative fuel use and the share of conventional vehicles using reformulated gasoline is held constant over the model's time horizon. This result is not sensitive to our assumptions concerning world oil prices or the cost of LPG. The quantity of oil displaced simply does not vary. Thus, we can conclude that, in the absence of new policy initiatives, that the US is not likely to attain EPACT's 2000 or 2010 fuel displacement goals.

Insights on the Importance of Transitional Barriers

The results of these first two base cases (without and with transitional barriers) demonstrate three features of the transitional study. First, there is a good degree of consistency with the AFTM 2010 results presented earlier, when using comparable LPG and oil prices, and omitting transitional barriers. Secondly, transitional barriers are significant in restricting the penetration of alternative fuels and vehicles and are likely to prevent the attainment of EPACT's 2000 and 2010 fuel replacement goals, absent additional policies. Finally, as will be demonstrated in subsequent policy cases that successfully induce alternative fuel use, transitional barriers (such as scale economies and the inconvenience of limited fuel availability) also promote specialization of the market in at most one or two alternative fuels. The convenience and cost savings attainable with specialization outweigh the benefits of diversity. This is in stark contrast to the diversity of fuel technologies introduced in the "no-transitional barriers" case.

3.4 EPACT Private and Local Rulemaking

As mentioned earlier, the USDOE has the authority under EPACT to require private fleets and those of state and local governments to purchase certain percentages of AFVs (as shown in Figure 12) if it determines that this is necessary to attain EPACT's fuel displacement goals. The effects of this Private and Local Rulemaking (P&L) policy option are examined in combination with most of the other policies considered below.[12] In each case, to implement this policy tool, we maintain the general scenario assumptions, but impose the "late rulemaking" fleet mandate as well.

For the base case scenario the P&L rule induces private (non-fleet) vehicle owners to purchase, by 2010, an additional 3% of AFVs. Thus, under the late rule a total of about 5% of new vehicle sales are AFVs by 2010. The P&L rule has little or no effect, however, on alternative fuel penetration or gasoline displacement. In particular, over all of the price scenarios, we find that the P&L rule increases the alternative fuel penetration in 2010 from 0.12% (without the P&L rule) to, at most, 0.37% of total fuel sales. This is simply because, given the low projected cost of gasoline, alternative fuels are not appealing to most fleets. Accordingly, the majority of vehicles purchases are FFVs that use gasoline. So, while the P&L rule can potentially triple the alternative fuel use, the absolute magnitude of the alternative fuel demand is still quite small. In addition, imposition of the P&L rule is not costless.

Various Policy Scenarios

Some of the policies examined, however, do lead to a significant quantity of fuel displacement. By definition, the Retail Alternative Fuel Sales Mandate (RAFSM) case achieves the 30% replacement goal by 2010. What makes this case of interest is not that it achieves mandated gasoline displacement, but the freely chosen mix of fuels and vehicles which comprise the mandated total. In addition, the net cost to consumers, fuel producers and vehicle manufacturers of attaining this goal is relevant. Under the base fuel price and tax scenario, a retail alternative fuel mandate requiring 30% displacement of petroleum will be satisfied largely by the use of imported methanol (22.5%), NGL's and hydrogen (4%), oxygenate blends (2.5%), and very small quantities of LPG and CNG (1% combined). This mix does not change in the presence of higher world oil prices, nor if the ethanol tax credit is indexed for inflation. The one case in which the mix changes substantially, is if LPG is available at a lower price than projected by EIAs AEO98, that is one comparable to that used in DOE's AFTM study (AFTM, USDOE 1996, Leiby 1993). In this case LPG could displace 15% of petroleum with the remaining displacement coming from methanol and oxygenate blends.

Other than the alternative fuel sales mandate policy, the policies that are most effective in inducing the displacement of petroleum are the Low Greenhouse Gas Tax Credit (LGHGTC) and Continued Ethanol Tax Credit (CRTC) policies. Both of these policies rely on substantial subsidization of ethanol

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[12]This policy tool is not used in conjunction with all other policies for reasons of rationality. Specifically, we do not examine the effectiveness of fleet mandates in the presence of retail fuel sales mandates.

and other low-GHG fuels. Given base case fuel price projections these policies are still not sufficient to induce additional alternative fuel penetration. Given high world oil prices, however, these policies can be effective, particularly if the ethanol tax credit is adjusted for inflation to maintain its present value of $0.54 per physical gallon. Given high world oil prices, the LGHGTC induces petroleum displacement from 9.1% to 11.3% by 2010. If, in addition, the tax credits are also inflation adjusted 22.3% of petroleum can be displaced by 2010. The CRTC policy case is less effective since it only targets ethanol. Nonetheless, it is able to induce a 16% displacement of petroleum if the tax credit is maintained at its present real value.

These results lead us to several observations. First, in a market economy where vehicle manufacturers, fuel suppliers, and consumers all make independent decisions, the efficacy of government policies to reduce the dependence of the United States transportation sector on petroleum is highly dependent on the world price of petroleum. Second, the penetration of alternative fuels and AFVs depends on the fuel retail infrastructure, the scale of production of AFVs, and other transitional barriers. Absent new government policies to reduce these transitional barriers, it is likely that the United States will not achieve EPACT's 2000 and 2010 displacement goals. Governmental policies can effectively reduce these barriers and can allow alternative fuels to compete in the marketplace with gasoline. This could be very valuable should oil prices rise. However, given the current and expected low price of petroleum in the world today, the policies that we have examined are not likely to be sufficient without large and sustained incentives.

Table 7: Fuel Displacement Summary Table
AEO Base, Higher LPG Cost

Policy	Gasoline Displacement in 2010*	Total Displacement 1996-2010	Welfare Cost**	Incremental Displacement Cost***
Units	Percent	Bill GGE	Bill $96	$/GGE
Base (No Policy)	9.2%	178.82	0.000	No Change
Late Private (P&L) Rule	9.2%	178.80	1.72	No Change
Late Private Rule with 50% Fuel Mandate	9.7%	183.18	3.94	1.56
Continued Ethanol Tax Credit	9.2%	178.88	0.04	0.46
Low-GHG Fuel Subsidy	9.3%	179.07	1.27	0.44
Increased CAFE Standards	9.2%	178.85	0.31	0.36
Retail Alternative Fuel Sales Mandate	30.0%	343.40	26.57	0.29
Ensign Bill: $0.50 AF credit thru 2004	9.2%	180.24	0.22	0.28
Extended Ensign Bill: $0.25 AF credit thru 2009	9.3%	180.15	0.20	0.26
Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.3%	182.98	1.13	0.50
Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.4%	180.65	0.49	0.47
Extended Ensign Bill: $0.50 AF credit thru 2009	9.3%	181.17	0.37	0.29
Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	9.6%	184.82	1.59	0.52
No Transitional Barriers (Long-Run)	14.9%	224.20	NA	NA
P&L Rule Plus Continued Ethanol Tax Credit	9.3%	179.16	1.80	8.35
P&L Rule Plus Low-GHG Fuel Subsidy	9.3%	179.59	1.90	4.07
P&L Rule Plus Increased CAFE Standards	9.3%	179.35	2.37	3.10
P&L Rule Plus Ensign Bill: $0.50 AF credit thru 2004	9.3%	180.32	1.99	2.24
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit thru 2009	9.3%	180.06	1.92	2.68
P&L Rule Plus Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.4%	183.90	3.13	1.14
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.3%	180.27	2.10	2.58
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit thru 2009	9.4%	181.75	2.21	1.41
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	9.8%	187.02	3.91	0.95

* This includes displacement from both alternative fuels and replacement fuels, including the replacement fuel content of gasoline and RFC.
**The welfare cost is the discounted sum of consumer and producer surplus net of any taxes or subsidies over the 1996-2010 time horizon plus any costs or benefits associated with the terminal period, relative to Base/current policy.
*** The cost per gallon is the discounted welfare cost divided by the discounted sum of fuel displacement over the 1996-2010 time horizon plus any costs, benefits and displacement associated with the terminal period. "No Change" signifies no change in the total displacement. "Decrease" indicates a decrease in total displacement.

Table 8: Fuel Displacement Summary Table AEO HWOP, Higher LPG Cost				
Policy	Gasoline Displacement in 2010*	Total Displacement 1996-2010	Welfare Cost**	Incremental Displacement Cost***
Units	Percent	Bill GGE	Bill $96	$/GGE
Base (No Policy)	9.4%	179.50	0.00	No Change
Late Private (P&L) Rule	9.3%	178.29	2.33	Decrease
Late Private Rule with 50% Fuel Mandate	10.0%	182.71	2.51	1.20
Continued Ethanol Tax Credit	9.3%	178.80	2.02	Decrease
Low-GHG Fuel Subsidy	11.3%	182.82	5.02	0.51
Decreased CAFE Standards	11.1%	188.01	0.46	0.10
Retail Alternative Fuel Sales Mandate	30.0%	341.69	14.82	0.17
Ensign Bill: $0.50 AF credit thru 2004	9.3%	179.84	0.79	Decrease
Extended Ensign Bill: $0.25 AF credit thru 2009	9.4%	179.97	0.77	Decrease
Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.6%	187.01	2.78	Decrease
Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.5%	181.35	1.22	Decrease
Extended Ensign Bill: $0.50 AF credit thru 2009	9.4%	181.78	1.12	Decrease
Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	10.1%	188.13	2.86	Decrease
No Transitional Barriers (Long-Run)	17.9%	247.03	NA	NA
P&L Rule Plus Continued Ethanol Tax Credit	9.3%	178.30	2.34	Decrease
P&L Rule Plus Low-GHG Fuel Subsidy	9.3%	179.14	2.51	Decrease
P&L Rule Plus Decreased CAFE Standards	NA	NA	NA	NA
P&L Rule Plus Ensign Bill: $0.50 AF credit thru 2004	9.3%	179.97	2.56	Decrease
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit thru 2009	9.4%	180.11	2.50	Decrease
P&L Rule Plus Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	NA	NA	NA	NA
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.7%	183.33	3.43	Decrease
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit thru 2009	23.0%	308.49	7.64	0.14
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	10.5%	192.05	5.29	4.94

Table 9: Fuel Displacement Summary Table **AEO HWOP, Higher LPG Cost, Tax Credits Inflation Adjusted**				
Policy	Gasoline Displacement in 2010*	Total Displacement 1996-2010	Welfare Cost**	Incremental Displacement Cost***
Units	Percent	Bill GGE	Bill $96	$/GGE
Base (No Policy)	9.3%	178.63	0.00	No Change
Late Private (P&L) Rule	9.3%	178.91	1.78	9.77
Late Private Rule with 50% Fuel Mandate	10.1%	183.02	1.96	0.24
Continued Ethanol Tax Credit	16.5%	199.65	9.20	0.34
Low-GHG Fuel Subsidy	22.3%	245.13	20.05	0.43
Increased CAFE Standards	11.8%	198.53	0.52	0.04
Retail Alternative Fuel Sales Mandate	30.0%	341.58	25.41	0.28
Ensign Bill: $0.50 AF credit thru 2004	9.3%	179.83	0.13	0.18
Extended Ensign Bill: $0.25 AF credit thru 2009	9.4%	180.06	0.13	0.16
Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.6%	186.59	1.20	0.47
Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.5%	181.36	0.56	0.39
Extended Ensign Bill: $0.50 AF credit thru 2009	9.5%	182.52	0.63	0.30
Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	10.1%	189.22	2.41	0.46
No Transitional Barriers (Long-Run)	16.9%	239.40	NA	NA
P&L Rule Plus Continued Ethanol Tax Credit	17.3%	206.53	11.93	0.41
P&L Rule Plus Low-GHG Fuel Subsidy	22.3%	247.20	21.67	0.45
P&L Rule Plus Increased CAFE Standards	NA	NA	NA	NA
P&L Rule Plus Ensign Bill: $0.50 AF credit thru 2004	9.3%	179.80	1.85	2.65
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit thru 2009	9.4%	180.04	1.85	2.40
P&L Rule Plus Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	13.6%	244.61	5.88	0.16
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.7%	183.72	2.83	1.11
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit thru 2009	9.8%	186.47	3.03	0.78
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	10.6%	191.87	4.61	0.69

Table 10: Fuel Displacement Summary Table AEO HWOP, Lower LPG Cost				
Policy	Gasoline Displacement in 2010*	Total Displacement 1996-2010	Welfare Cost**	Incremental Displacement Cost***
Units	Percent	Bill GGE	Bill $96	$/GGE
Base (No Policy)	9.3%	178.903	0.00	No Change
Late Private (P&L) Rule	9.4%	179.221	1.72	7.90
Late Private Rule with 50% Fuel Mandate	10.0%	183.937	3.26	1.14
Continued Ethanol Tax Credit	9.4%	179.031	1.65	0.28
Low-GHG Fuel Subsidy	11.0%	182.511	4.63	0.36
Retail Alternative Fuel Sales Mandate	30.0%	343.130	7.85	0.08
Ensign Bill: $0.50 AF credit thru 2004	9.4%	180.852	0.17	0.15
Extended Ensign Bill: $0.25 AF credit thru 2009	9.5%	180.797	0.11	0.10
Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.8%	190.423	2.44	0.40
Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.5%	181.420	0.32	0.24
Extended Ensign Bill: $0.50 AF credit thru 2009	9.7%	185.102	0.81	0.25
Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	20.5%	240.796	0.09	0.00
No Transitional Barriers (Long-Run)	25.5%	280.552	NA	NA
P&L Rule Plus Continued Ethanol Tax Credit	9.4%	179.303	1.73	6.02
P&L Rule Plus Low-GHG Fuel Subsidy	9.4%	180.151	1.89	2.68
P&L Rule Plus Ensign Bill: $0.50 AF credit thru 2004	9.4%	181.145	1.95	1.49
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit thru 2009	9.5%	180.978	1.84	1.63
P&L Rule Plus Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.8%	190.816	4.31	0.69
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	10.0%	186.555	2.97	0.78
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	20.6%	239.504	0.96	0.02

Table 11: Fuel Displacement Summary Table AEO Base, Higher LPG Cost, Oil Shock in 2005				
Policy	Gasoline Displacement in 2010*	Total Displacement 1996-2010	Welfare Cost**	Incremental Displacement Cost***
Units	Percent	Bill GGE	Bill $96	$/GGE
Base (No Policy)	9.3%	177.88	0.000	No Change
Late Private (P&L) Rule	9.3%	178.07	1.725	No Change
Late Private Rule with 50% Fuel Mandate	11.2%	185.50	1.32	0.11
Continued Ethanol Tax Credit	9.3%	177.97	0.02	0.37
Low-GHG Fuel Subsidy	9.4%	178.24	2.79	0.31
Retail Alternative Fuel Sales Mandate	30.0%	342.82	5.41	0.06
Ensign Bill: $0.50 AF credit thru 2004	9.3%	179.35	0.13	0.16
Extended Ensign Bill: $0.25 AF credit thru 2009	9.4%	179.54	0.11	0.13
Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.5%	182.38	0.90	0.37
Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.4%	179.89	0.33	0.31
Extended Ensign Bill: $0.50 AF credit thru 2009	9.4%	181.04	0.24	0.15
Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	9.8%	185.08	1.30	0.36
No Transitional Barriers (Long-Run)	18.3%	246.08	NA	NA
P&L Rule Plus Continued Ethanol Tax Credit	9.3%	178.35	1.76	6.60
P&L Rule Plus Low-GHG Fuel Subsidy	9.4%	178.97	4.56	0.46
P&L Rule Plus Increased CAFE Standards	9.5%	179.04	1.02	0.15
P&L Rule Plus Ensign Bill: $0.50 AF credit thru 2004	9.4%	179.60	1.87	1.87
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit thru 2009	NA	NA	NA	NA
P&L Rule Plus Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.5%	183.68	2.84	0.91
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.4%	180.63	2.01	1.54
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit thru 2009	11.8%	197.96	1.76	0.11
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	10.4%	190.056	3.75	0.63

Table 12: Fuel Displacement Summary Table AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted				
Policy	Gasoline Displacement in 2010*	Total Displacement 1996-2010	Welfare Cost**	Incremental Displacement Cost***
Units	Percent	Bill GGE	Bill $96	$/GGE
Base (No Policy)	9.2%	178.86	0.00	No Change
Late Private (P&L) Rule	9.2%	178.88	1.72	No Change
Late Private Rule with 50% Fuel Mandate	9.7%	183.118	3.5	1.60
Continued Ethanol Tax Credit	10.9%	182.70	7.00	0.55
Low-GHG Fuel Subsidy	17.4%	210.99	17.68	0.68
Increased CAFE Standards	9.2%	178.96	0.29	0.37
Retail Alternative Fuel Sales Mandate	30.0%	343.30	37.84	0.41
Ensign Bill: $0.50 AF credit thru 2004	9.3%	180.46	0.26	0.28
Extended Ensign Bill: $0.25 AF credit thru 2009	9.3%	180.04	0.14	0.22
Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.4%	183.07	1.13	0.49
Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.4%	180.56	0.41	0.43
Extended Ensign Bill: $0.50 AF credit thru 2009	9.4%	181.36	0.39	0.29
Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	9.6%	185.11	1.62	0.50
No Transitional Barriers (Long-Run)	14.6%	223.13	NA	NA
P&L Rule Plus Continued Ethanol Tax Credit	11.4%	183.32	9.03	0.66
P&L Rule Plus Low-GHG Fuel Subsidy	18.0%	219.64	21.45	0.74
P&L Rule Plus Increased CAFE Standards	9.8%	180.41	2.54	0.92
P&L Rule Plus Ensign Bill: $0.50 AF credit thru 2004	9.2%	180.22	1.93	2.51
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit thru 2009	9.3%	180.05	1.89	2.84
P&L Rule Plus Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	9.4%	183.86	3.09	1.14
P&L Rule Plus Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	9.4%	180.93	2.28	1.99
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit thru 2009	9.4%	181.37	2.12	1.55
P&L Rule Plus Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	9.8%	187.52	4.00	0.92

3.5 Low-GHG Tax Credit

Of particular interest for the long-run sustainability of transportation is our ability to stabilize, or actually decrease, the transportation sector's contribution to global warming. A focus on gasoline use is especially appropriate since the transportation sector is responsible for about 32% of the CO_2 emissions in the US, and gasoline contributes 63% of the transportation sector's total (Davis, 1997, Tables 7.9, 7.11). One of the interesting policies suggested for reducing GHG emissions from the transportation sector, is to offer a tax credit for low GHG emission fuels. The tax credit is structured such that a zero GHG emission fuel would gain the full $.80 per GGE credit and gasoline would receive a credit of zero.

This tax credit is designed so that the incentive for E85 would be equal to that currently available, namely $0.54 per physical gallon, provided the ethanol is produced from cellulosic biomass. Other fuels would receive a prorated credit or tax depending on whether their GHG emissions are lesser or greater than those of gasoline. The resulting subsidy corresponds to an incentive of $62.7 per MT CO_2-equivalent (or $230 per MT of carbon) reduction. Shown in Figure 13 are the full fuel cycle GHG emissions of each fuel based on estimates from the GREET version 1.4 (Wang, 1998). Additionally shown are the GHG emissions from fuel production and use only; excluding emissions from vehicle production. Lastly shown are the cents per gasoline gallon equivalent (GGE) credits or taxes based on the GHG emissions from fuel production and use.

Despite the substantial magnitude of this incentive, the low-GHG tax credit is not effective in increasing alternative fuel use given the base-case oil price projections. Given higher world oil prices, the LGHGTC policy increases alternative fuel use to 3% of demand by 2010, all E85. If in addition to high world oil prices, the tax credit is maintained at its present value real level of $0.54 per physical gallon rather than allowing its value to be eroded by inflation, then this policy is very effective in inducing alternative fuel use. In this case, the fuel share of E85 rises to 14% and M85 rises to 5% by 2010. Although early E85 comes from corn, by 2010 the E85 is predominantly from biomass, receiving a $0.74 per GGE credit. Total oil displacement under this scenario is 22% by 2010. This policy could go a long way towards achieving EPACT's goal of a 30% fuel displacement by 2010.

The new vehicle production shares tell a similar story: the AFVs produced are principally dedicated alcohol vehicles, explaining the fuel choices of E85 and M85. This reflects the lower cost and higher vehicle efficiency of the dedicated vehicles given that consumers and producers anticipate that this program will remain in effect over the time horizon of the model.

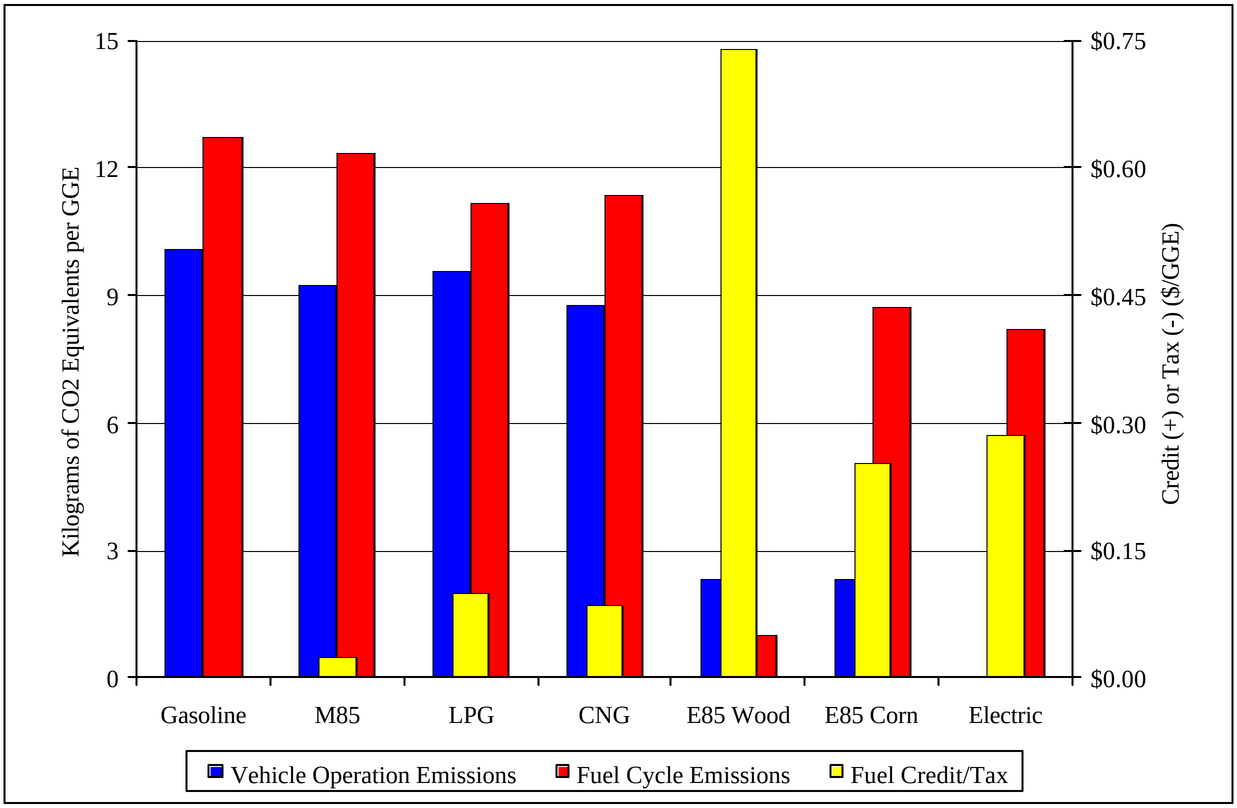


Figure 13: Emissions and GHG Tax Credit for each Motor Fuel

3.6 Continued Ethanol tax credit

As a variation on the low GHG policy case we simply assume that the current ethanol tax credit, due to be terminated in 2007, will be continued in its current form through the forecast horizon.[13] We call this the "Continued Ethanol tax credit" case. This policy case is quite similar to the low GHG fuel subsidy case, since by design the magnitude of the fuel subsidy for E85 from biomass is the same in both cases. Given the base case price/tax scenario, this policy is not effective in encouraging alternative fuel use. Only when the ethanol credit is maintained constant in real dollars and when there are high world oil prices is continuation of the ethanol tax credit effective. When these additional assumptions are made, however, the CRTC is able to encourage 11% E85 use by 2010. No other alternative fuel is encouraged, however, and so we can conclude that this policy is less effective overall than the LGHGTC policy in encouraging the use of alternative fuels. In addition, this credit also does not add encouragement for an earlier switch to biomass as the feedstock for ethanol is not as great in this scenario.

[13]The ethanol tax credit is $0.54 per physical gallon, or $0.68 per GGE for E85. In this case, corn and cellulosic ethanol are treated (subsidized) equally. In the previous low-GHG fuel credit case, cellulosic ethanol is given the maximum subsidy, while corn receives less credit since has higher emissions than cellulosic ethanol.

The costs per metric ton of CO_2-equivalent and the overall effectiveness of the two alternative GHG policies are shown in Table 13. When comparing the cost per ton of the two policies, it is important to make the distinction between the costs in terms of tax dollars foregone (column 4 in Table 13) and the costs per ton to the nation's economy after subtracting out transfers that benefit the fuel producing sectors (column 5). As is seen from the table, continuing the ethanol tax credit in its current form is not as cost-effective as the tax cut for low GHG fuels in reducing GHG emissions (since the E85 is derived from corn in the early years), or in attaining EPACT's gasoline displacement goal (since LPG qualifies for a subsidy in addition to E85). In addition, continuing the ethanol tax credit is more expensive to the economy on a per-ton basis than a tax policy specifically targeted to reduce GHG emissions. Nonetheless, it is still an effective second-best policy. We cannot comment on whether either of these policies is, in fact, desirable from a national perspective. In our view that judgement is a political decision.

Table 13: Summary Results Across GHG Cases
(Lower Cost LPG Assumption)

	NPV Incremental Benefits (Bill $94)	GHG (Bill MT of CO_2)	Tax/GHG[14] ($94/MT of CO_2)	Cost/GHG ($94/MT of CO_2)
Tax Cut for Low GHG Fuels	-25.5	-0.915	66.65	27.84
Continue Renewable Fuel Credit	-25.2	-0.759	63.84	33.24

3.7 Increased CAFE Standards

This policy case explores the impact of increasing the CAFE standard by 1.0 MPG. In the case examined here, we consider what would happen if vehicle manufacturers respond to increased CAFE standards by offering essentially the same mix of vehicle models with the same MPG, but choose to either pay the fine or meet the standards by introducing AFVs. Currently, CAFE standards are binding, and vehicle manufacturers are offering FFVs, probably to gain CAFE credits.[15] Thus while it may be unlikely that manufacturers would meet increased CAFE standards solely with AFVs, the current vehicle manufacturer behavior suggests that AFVs will play some role in meeting stricter CAFE standards. In this case the percentage of AFVs that can be introduced into the fleet sales mix before the CAFE standard is no longer binding rises to 11% for dual and 5.5% for dedicated vehicles.

The model results indicate that manufacturers produce alcohol FFVs early, both for CAFE credits and

[14]To convert to dollars per metric tonne of carbon, multiply the cost per tonne by 3.67 (the ratio of the molecular weight of carbon dioxide to carbon).

[15]According to the New York Times (October 16, 1997) Ford plans to build 250,000 cars, mini-vans and pickup trucks in a four-year period that can run on ethanol mixtures. Other manufacturers are following suit.

to meet the existing EPACT fleet mandates. The early alcohol FFVs meet regulatory requirements, but do not use much alcohol fuel at all. After 2004, manufacturers begin to produce dedicated alcohol AFVs. Since the CAFE credits for dual/flex AFVs end in 2005, and since the cost of ethanol declines due to exogenous technical improvements, the production mix shifts toward dedicated alcohol vehicles in later years, leveling out at the level where CAFE credits are exhausted (5.5%). Initially, the fuel requirements of the dedicated alcohol vehicles are met by methanol, but as ethanol costs decline after 2005, biomass ethanol becomes the fuel of choice.[16]

3.8 AFV Fuel Share and Gasoline Displacement Results Under Higher Oil Prices

Since our results showed that it is difficult for alternative fuels to make a substantial market penetration under that comparatively low oil prices projected in the AEO base case, we sought to determine the effects higher oil prices on the use of alternative fuel. We tested four distinct alternative fuel policies under a range of crude oil prices higher than those in the Annual Energy Outlook base case. The policy tests were conducted given upward shifts in the Annual Energy Outlook base case oil price path of between $0 and $20 per barrel by 2005.[17] The results are summarized in terms of AFV fuel share and gasoline displacement achieved in the year 2010. As the figures and tables below show, an increase in the expected world oil price will only produce significant alternative fuels penetration when combined with sufficiently strong alternative fuels policies.

Estimating the Oil Price and Retail Fuels Relationship

In order to determine the effects of an oil price increase on alternative fuel use we first estimated the effect of oil price on retail motor fuel costs. We benchmarked effect on the basis of the equilibrium price relationships implied by the AEO99 Base, High and Low oil price scenarios. While other methods may be available, this simple technique is transparent and produces results which are consistent with common thinking. The AEO pseudo-data revealed fairly stable linear relationships over the forecast horizon and the different scenarios. The estimated equation is:

$$P_{f,t} = \alpha_f + \beta_f P_{oil,t}$$

for fuel f = {gasoline, natural gas, and LPG}.

[16]For more information on AFVs and CAFE, see (Rubin and Leiby, 2000).

[17]Each oil price shift, from $0 to $20 in $2/bbl increments, was imposed on top of the AEO base oil price projections. The fuel shift is achieved gradually over five years (by 2005) and sustained thereafter. It is helpful to bear in mind that the high oil price shift serves as a rough proxy for both changing oil market conditions and/or the imposition of a carbon tax. Of course, the latter would have a different effect on the costs of some alternative fuels than the former.

The slope coefficients $ß_f$ which can be drawn out from this approach are all positive and of the approximate magnitude one might expect.

Wholesale Motor Fuel	**Slope (ß)*** ($ price increase/$ crude oil increase)
Gasoline	1.00
Nat Gas	0.07
LPG	1.27
*These coefficients all apply to prices measured on a BTU-equivalent basis.	

The gasoline price coefficient is approximately one, reflecting direct pass-through of crude oil cost to gasoline price on a BTU-basis. The natural gas slope is small, reflecting a weak positive link between gas and oil prices. Crude oil and natural gas are substitutes, while crude oil and gasoline are the inputs and outputs of a production process, so we would expect the relationships to differ. The LPG cost slope is greater than one, reflecting, perhaps, a sort of "byproduct" nature of LPG from refining and natural gas production.

The TAFV code was revised to allow shifting of motor fuel prices along with any exogenous crude oil price shift, using the specified slopes (ß). Oil price shifts from $2 to $20 were considered. This shift is achieved by 2005, and the intervening years (2000-2004) are linearly interpolated (i.e., one additional fifth of the total shift is achieved each year). Note that this leads to much higher oil prices than the AEO High World Oil Price case. The AEO99 High Oil Price scenario is not a linear shift from the Base Price projection, but seems to correspond closest to somewhere between the $6/BB and $10/BBL shifts we consider here.

Results of Oil Price Sensitivity Cases

The shifted oil price projections were applied to five policy cases: Base (No New Policy), Private and Local Fleet Rule, Private and Local Fleet Rule With 50% Fuel Use, Low-GHG Fuel Tax Credit with Tax Credits Inflation Adjusted, and 30% Alternative Fuels Sales Mandate.

The 2010 alternative fuel demand shares and gasoline displacements are given in the figures and tables below.. For the Base Case (no new policies) there is essentially no alternative fuel penetration, even for large oil price shifts. In the base case, the oil price shift never rises high enough to overcome the combined obstacles posed by transitional barriers and the long-run cost disadvantages of alternative fuels. Apparently these combined obstacles are substantial (in excess of $20/BBLl oil, or $0.43/GGE.

For the “Private and Local Fleet Rule,” a policy mandating vehicle purchases, there still is essentially no effect except in the case of very large oil price increases. While the kinked nature of these results seem bewildering, it reflects that while the mandates may overcome barriers due to economies of scale for vehicle production, another significant “barrier”remains to be overcome (most likely fuel availability infrastructure). If oil prices are sustained at a *much* higher level than the base case, there is sufficient inducement to overcome this second barrier, and, when coupled with the early vehicle production activity required by the Private and Local Fleet rule, high levels of alternative fuel and vehicle use may be observed by 2010..

The most interesting result is for the “Private and Local Fleet Rule for fleet vehicles coupled with 50% Alternative Fuel Use” policy. Such a policy is very costly on a per-barrel-displacement basis for lower oil prices. The policy also has little effect on alternative fuel penetration until the oil price shift reaches about $6-$8/BBL. Then it has an increasingly powerful effect on inducing alternative fuel use. We see a very smooth transition (as a function of oil price increases) with the achievement of the 30% gasoline replacement goal around the $18/bbl ($0.39/GGE) oil price increase mark. This suggests that requiring fleets to use alternative fuel forces the creation of some refueling infrastructure (assuming commercial refueling of these fleet AFVs), and the remaining barriers are more modest and smooth.

We know that at current oil prices, the Private and Local Rule is by far the most expensive policy in terms of $/GGE displaced. This is in part because it imposes costs but induces essentially no alternative fuel use. But the Private and Local Rule unit-displacement costs decline rapidly as oil prices rise, until the Private and Local Rule becomes both an effective and cheap option at very high oil prices! This is because, given sufficiently high oil prices, it serves only to push decision-makers over the initial scale-availability barriers, and then it "gets out of the way." By getting out of the way, we mean that it has no marginal costs or effects, since market demand shares exceed the bounds imposed by the mandate.[18]

[18]However, we are not sure that we are properly measuring, or can properly measure, the disutility to fleets of constraining their vehicle choice.

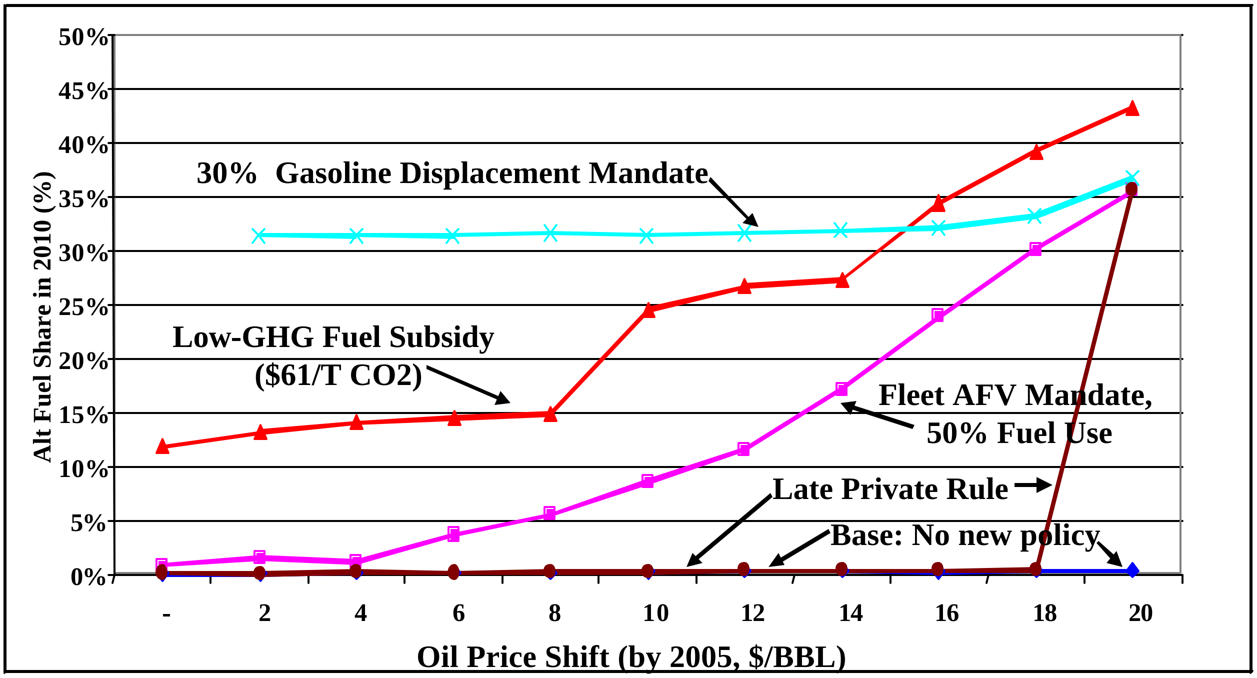


Figure 14: Alternative Fuel Share in 2010 for Various Oil Price Shifts

Table 14: Alternative Fuel Share in 2010 for Various Oil Price Shifts

Case Descriptor	Base	Private and Local Fleet Rule	Private and Local Fleet Rule With 50% Fuel Use	Low-GHG Fuel Subsidy, Tax Credits Inflation Adjusted	30% Alternative Fuels Sales Mandate
Base WOP	0%	0%	1%	12%	31%
Base WOP + $2	0%	0%	2%	13%	31%
Base WOP + $4	0%	0%	1%	14%	31%
Base WOP + $6	0%	0%	4%	15%	31%
Base WOP + $8	0%	0%	6%	15%	32%
Base WOP + $10	0%	0%	9%	25%	31%
Base WOP + $12	0%	0%	12%	27%	32%
Base WOP + $14	0%	0%	17%	27%	32%
Base WOP + $16	0%	0%	24%	34%	32%
Base WOP + $18	0%	1%	30%	39%	33%
Base WOP + $20	0%	36%	36%	43%	37%

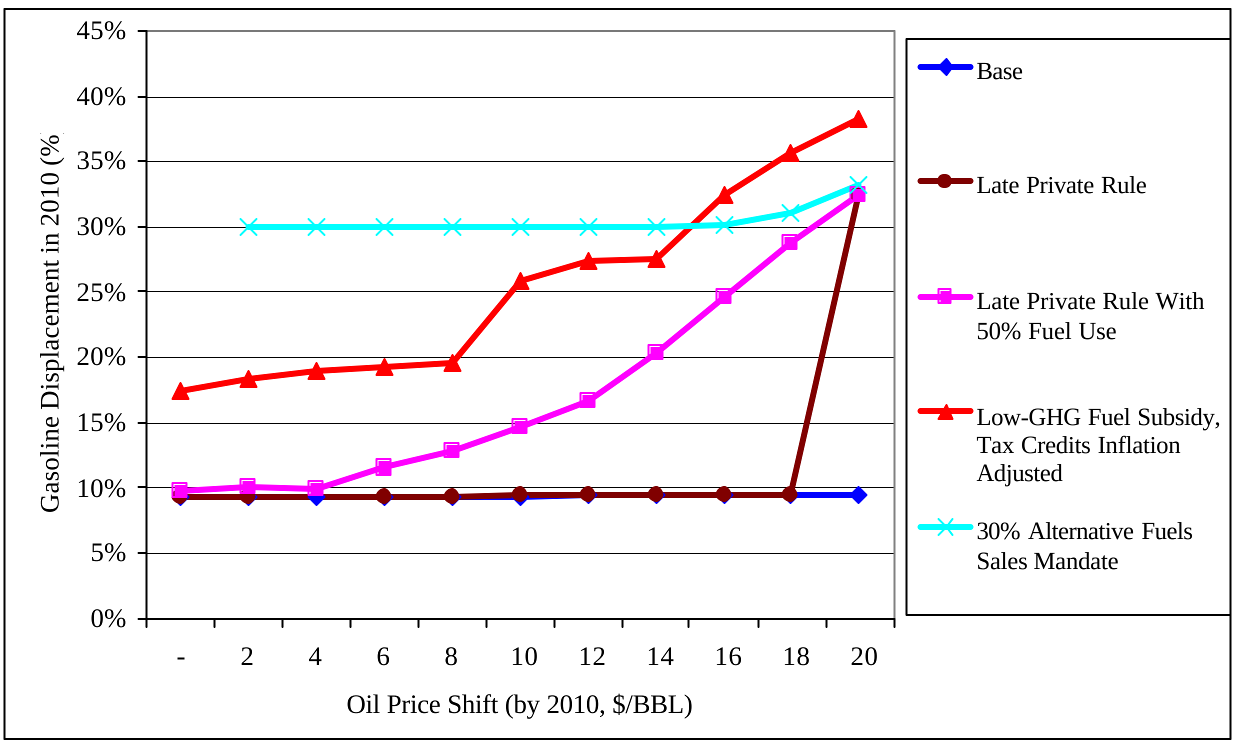
For the "Low-GHG Fuel Subsidy" policy, there is 12% alternative fuel use achieved at current oil prices. The Low-GHG Fuel Subsidy case entails a $0.73/GGE tax credit for a zero-GHG fuel (essentially cellulosic ethanol), and much lesser subsidies for the other alternative fuels which still emit GHGs. Under the Low-GHG subsidy, the 30% gasoline replacement goal is attained for an oil price shift of around $15/BBL ($0.32/GGE).

We could draw a similar graph to Figure 14, but sweep out over a range of increasing GHG taxes and subsidies. The result would be different, since the mix of fuels favored would differ. But one lesson seems to be that even if we don't expect oil prices to rise by $20/BBL, some combination of oil price changes and sustained GHG price incentives could induce significant alternative fuel use. Furthermore, and most interestingly, we find that there may be an intermediate range of price conditions where alternative fuels can only get started slowly, and where a "transitional policy" such as the Private and Local Rule (with 50% fuel use) could be a powerful and comparatively inexpensive way to promote the social objective of alternative fuel use.

Table 15: Gasoline Displacement in 2010 for Various Oil Price Shifts

Case Descriptor	Base	Private and Local Fleet Rule	Private and Local Fleet Rule With 50% Fuel Use	Low-GHG Fuel Subsidy, Tax Credits Inflation Adjusted	30% Alternative Fuels Sales Mandate
Base WOP	9%	9%	10%	17%	30%
Base WOP + $2	9%	9%	10%	18%	30%
Base WOP + $4	9%	9%	10%	19%	30%
Base WOP + $6	9%	9%	12%	19%	30%
Base WOP + $8	9%	9%	13%	20%	30%
Base WOP + $10	9%	9%	15%	26%	30%
Base WOP + $12	9%	9%	17%	27%	30%
Base WOP + $14	9%	9%	20%	28%	30%
Base WOP + $16	9%	9%	25%	32%	30%
Base WOP + $18	9%	10%	29%	36%	31%
Base WOP + $20	9%	32%	32%	38%	33%

Figure 15: Gasoline Displacement in 2010 for Various Oil Price Shifts



4.0 Model Results Compared to EIA Data

As a check on how well the model is able to reproduce observed market outcomes we compare our base case results with recent historical data on AFV and AF use gathered by the EIA (2000). The first TAFV projection year is 1996, this means that vehicle and fuel prices, and the mix and quantity of vehicle and fuel sales, are endogenous. In comparing with EIA data, caution is necessary because of differences between the way EIA presents information and the way in which comparable information is tracked in the model. For example, for CNG vehicles we combine our flexible and dedicated categories to compare with the EIA's undifferentiated CNG vehicle category (EIA 2000, Table 1). Other adjustments are also made. Caution is also necessary because the share of new vehicle sales that are alternatively fueled is 1.4%, and use of alternative fuels is at most 0.12% in the base case. This means that we are examining in great detail a very small portion of vehicle and fuel demand. The more disaggregated the examination, the greater is the likelihood for solution discrepancies.[19] Table 16 shows the early year estimated AFV sales given the base case prices assuming no new policies. Table 17 shows the difference in the number of vehicles estimated by the TAFV model less those estimated to be on the road by EIA.

Table 16: AFVs Sold in Base Case

Year	Alcohol Dedicated	Alcohol Flexible	CNG Dedicated	CNG Flexible	LPG Dedicated	LPG Flexible	Electric Dedicated
1996	3,939	49,000	33,000	31,000	131,000	96,000	3,818
1997	6,000	109,000	44,000	32,000	124,000	120,000	5,000
1998	10,000	213,000	50,000	33,000	118,000	140,000	7,000
1999	13,000	321,000	54,000	33,000	111,000	157,000	10,000
2000	16,000	435,000	56,000	34,000	104,000	171,000	15,000

Table 17: Differences in AFVs Sold TAFV Minus EIA

Year	Alcohol Dedicated	Alcohol Flexible	CNG All	LPG All	Electric Dedicated
1996	3,939	24,205	13,730	17,000	692
1997	6,000	-2,059	18,466	33,000	743
1998	10,000	-117,334	19,261	46,000	2,004
1999	13,000	-306,508	9,032	49,000	5,743
2000	16,000	NA	7,616	62,000	7,764

[19]Technically, the TAFV model has non-linear constraints and a non-linear objective function. This means that the model results are classified as locally optimal. Changes in starting points, therefore, can lead to slightly different solutions. We have performed an extensive amount of testing and are confident that the broader conclusions are robust to this potential source of bias.

As shown in Table 18, for most vehicle types, the TAFV model is able to come reasonably close to EIA's estimates of the on-road AFV stock. The most significant departure is an under-estimate of the number of alcohol flexibly-fueled vehicles purchased. The category underestimated included the production of FFV vans and trucks for the purposes of CAFE credits. The Energy Information Administration assumes that these new FFVs use little-to-no alternative fuel, and the TAFV backcasts the same result. We also overestimate the number of dedicated alcohol vehicles that would be sold. However, the number of vehicles involved (a few thousand) is very small fraction of total number of vehicles sold (less than one-tenth of one percent). The discrepancy suggests that we do probably do not assign a large enough penalty to the low availability of M85 and E85.

Table 18: Percent Differences in AFVs Sold TAFV Minus EIA

Year	Alcohol Dedicated	Alcohol Flexible	CNG All	LPG All	Electric Dedicated
1996	100	49	21	7	18
1997	100	2	24	14	15
1998	100	-55	23	18	29
1999	100	-95	10	18	57
2000	100	NA	8	23	52

Table 19: Fuel Demand Quantities From TAFV

(Thousand Gasoline Gallon Equivalents per Year)

Year	Conventional Gasoline	Reformulated Gasoline	M85	E85	CNG	LPG	Electricity	Total Alt Fuel
1996	77,200,499	35,997,097	3,361	2,603	42,000	86,111	2,890	136,965
1997	78,779,205	36,762,827	4,599	3,578	42,000	79,237	3,914	133,329
1998	80,363,554	37,532,065	6,343	4,530	42,000	72,636	5,228	130,737
1999	81,950,764	38,306,805	7,966	5,145	42,000	66,297	8,203	129,612
2000	83,540,396	39,082,995	9,936	5,212	42,000	60,213	11,923	129,284

Table 20: Percentage Difference in LDV Fuel USE

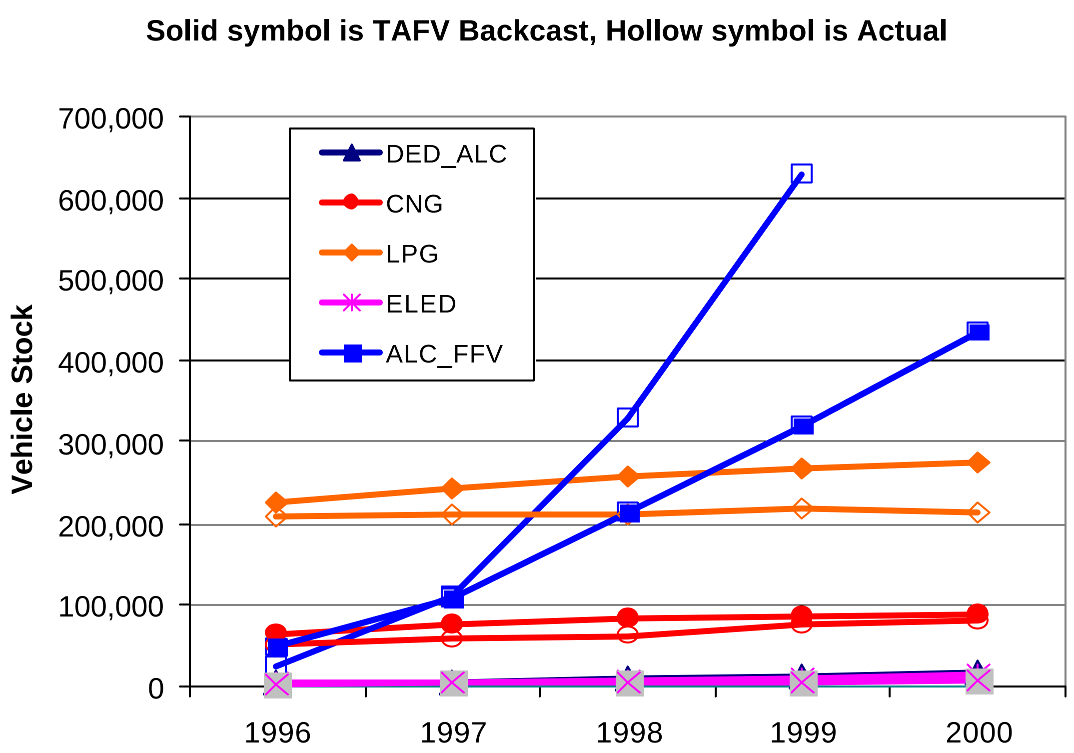
TAFV - EIA estimates

Year	Gasoline	M85	E85	CNG	LPG	Electricity	Total AF
1996	-4	47	73	42	-22	73	3
1997	-3	66	64	32	-33	74	-3
1998	-4	81	62	27	-46	77	-8
1999	-4	84	56	6	-66	82	-19
2000	-4	89	37	4	-77	86	-18

As is seen in Table 20, the TAFV model does a good job of matching EIA's estimates of historical gasoline sales, which represent 99.8% of fuel sales to the light-duty fleet, and total alternative fuel sales. It also does a fair job of matching the absolute quantity of the two principal alternative fuels actually used: CNG and LPG. On the other hand, it is more difficult for TAFV model to match the EIA estimates of recent alcohol fuel sales. We believe the discrepancy between model outcomes and recent observed market sales stems from several reasons. The first was mentioned above, namely that one cannot expect model precision to be high, on percentage terms, when examining very small model detail (e.g., individual sales for 5 alternative fuels whose volumes jointly comprise at most 0.12% of all fuel sales). Secondly, the underestimation of LPG fuel use may be attributable to the implicit assumption in the TAFV model that the existing LPG AFVs are dual fueled, and commercially (non-centrally) refueled. Hence, the TAFV model would conclude that the on-road stock of LPG vehicles (which it estimates fairly well) would use less alternative fuel than has been observed. In fact, they are most certainly centrally refueled. In addition, many of these CNG and LPG vehicles are fleet-owned, and may be driven more miles annually than an average vehicle. Future versions of the TAFV model should be adjusted to take these phenomena into account. The overestimate of M85 and E85 use stems from the TAFV model's overestimate of the number of dedicated alcohol vehicles.

Overall, the TAFV base case projection from 1996 to 2000 does a moderately good job of back-casting recent history. Total AFV stocks are accurate to within 15 percent, and the mix of vehicles chosen by the model is fairly close to EIA historical data. While the demand for alcohol fuels is over projected, and the demand for LPG was under projected, the quantities involved are small. In broad terms, the TAFV results match recent historical outcomes well: very little alternative fuel is being demanded (on the order of 0.1% of total fuel demand by light-duty vehicles). The only AFVs being sold in large numbers are alcohol FFVs, and they are using gasoline.

Figure 16: TAFV Modeled AFV Stock vs Actual



5.0 Conclusions

In contrast to earlier work, we find that transitional impediments are very important to the transportation sector and may overwhelm scenarios based on theoretically attainable production costs and market penetrations. In particular, the long run penetrations for alternative vehicles and fuels anticipated in the earlier EPACT 502(b) (DOE 1996) study are not likely to be achieved without measures to encourage the expansion of vehicle production and fuel availability. Limited retail fuel availability and vehicle production scale-economies are important. These features lead to substantially higher *initial* effective costs of alternative fuel vehicle services than were estimated for the long-run mature market outcomes in the EPACT 502b analysis for 2010.

More specifically, it may be hard for the alternative vehicle and fuel markets to get started. In terms of a policy tool, we do find that private (non-fleet) AFV purchases respond to fleet policies. We observe the expansion of household sector AFV demand in cases where fleets are induced or required to buy more AFVs. In part, this reflects vehicle production scale economies at work and our assumption that fleets refuel commercially. While we have not tried to determine the size of fleet mandates that may be necessary to attain EPACT's goals, it does appear that this is a viable policy tool. In the absence of any specific requirement that fleet AFVs use alternative fuel, fleet AFV purchase mandates may be met with dual or flex-fueled vehicles, and little alternative fuel may be used. However, if fleet AFVs are also mandated to use some fraction of alternative fuel, and if they refuel at publicly accessible commercial stations, then the barrier of limited retail fuel availability is diminished.

New technologies often require a network of specialized infrastructure, have scale economies of production, and may have a value which depends strongly on their compatibility with some other the existing product or technology ("hardware-software" compatibility). In these cases, the market tends toward specialization and the dominance of a single technology alternative. Alternative fuels and vehicles have each of these features to some degree. However, consumers have distinct tastes and circumstances, and thus collectively place a substantial value on having a diversity of product choices. Thus there is a tension between the cost-reducing effects of specialization and the utility-increasing effects of technology diversification. Given the costs and benefits estimates used in our model, we find that even in those cases where there is substantial AFV penetration due to policies (e.g., GHG-tax credit case), the costs of supplying technological diversity outweigh the benefits such that only one or two alternative fuel technologies are able to successfully enter the market.[20]

Finally, we note that the federal government does appear to have technically feasible policies at hand to lead the transportation sector towards a sustainable path, if sustainable is defined in terms of the light-duty vehicle sector not increasing, or even decreasing, its contribution to global warming. Specifically,

[20]It has been pointed out to us that while this result obtains in our deterministic analysis, in a world of great uncertainty the hedging and option value of diversity may sustain more alternative fuel technologies in the market, at least for a while.

the use of GHG tax credits or a continuation of the renewable fuel (ethanol) tax credit on the order of \$0.80 per GGE does appear to be sufficient incentive to stabilize GHG emissions from the transportation sector.

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Appendix 1: Cases Examined in the TAFV Modeling Study

Case Name	Assumptions				
	Fleet program	Fuel Taxes	Fuel Economy Credits	Other Alternative Fuel or Vehicle Policies	Comments
Base	Existing programs (Note 1)	Existing (Note 2)	Current law, including CAFE, for alternative fuels. (Note 3)	None	All of the following scenarios use these Base assumptions unless specifically noted otherwise.
Continued Ethanol Tax Credit	Existing programs (Note 1)	Existing, nominal ethanol subsidy continues indefinitely (phased down after 2007)	Current law, including CAFE, for alternative fuels. (Note 3)	None	The $0.54 per physical gallon ethanol subsidy is worth $0.68 per GGE for E85 and continues to be available through the model's time horizon.
Low-GHG Fuel Subsidy	Existing programs (Note 1)	Low-GHG fuel subsidies, declining with inflation (Note 5)	Current law, including CAFE, for alternative fuels. (Note 3)	None	The $0.54 per physical gallon ethanol subsidy is worth $0.68 per GGE for E85 made from biomass. Not shown in the fuel use graph is the changing mix of E85 from corn to biomass through time.
Increased CAFE Standards	Existing programs (Note 1)	Existing (Note 2)	Current law for Alternative fuels, new CAFE standards	CAFE standard increased 1 MPG, assume no change in conventional vehicle fleet	CAFE credit values unchanged from the base case, but dedicated and FFVs accumulate credits up until 5.5% and 11% of new vehicle sales in each year.
Retail Alternative Fuel Sales Mandate	Existing programs (Note 1)	Existing (Note 2)	Current law, including CAFE, for alternative fuels. (Note 3)	None	AF retail quantities must follow path to meet EPACT 502b goals (10% in year 2000, rising to 30% by 2010)
Ensign Bill: $0.50 AF credit thru 2004	Existing programs (Note 1)	$0.50/GGE (nominal) alt fuel tax credit from 1998-2004 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	None	Ensign fuel subsidies decline with 3% inflation

Case Name	Assumptions				
	Fleet program	**Fuel Taxes**	**Fuel Economy Credits**	**Other Alternative Fuel or Vehicle Policies**	**Comments**
Extended Ensign Bill: $0.25 AF credit thru 2009	Existing programs (Note 1)	$0.25/GGE (nominal) alt fuel tax credit from 1998-2009 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	None	Ensign fuel subsidies decline with 3% inflation
Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	Existing programs (Note 1)	$0.50/GGE (nominal) alt fuel tax credit from 1998-2004 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	CNG and LPG vehicle subsidy: $500 dual and $1000 dedicated (nominal $), 1998-2004	Ensign fuel and vehicle subsidies decline with 3% inflation
Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	Existing programs (Note 1)	$0.25/GGE (nominal) alt fuel tax credit from 1998-2009 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	CNG and LPG vehicle subsidy: $500 dual and $1000 dedicated (nominal $), 1998-2009	Ensign fuel and vehicle subsidies decline with 3% inflation
Extended Ensign Bill: $0.50 AF credit thru 2009	Existing programs (Note 1)	$0.50/GGE (nominal) alt fuel tax credit from 1998-2009 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	CNG and LPG vehicle subsidy: $500 dual and $1000 dedicated (nominal $), 1998-2009	Ensign fuel and vehicle subsidies decline with 3% inflation
Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	Existing programs (Note 1)	$0.50/GGE (nominal) alt fuel tax credit from 1998-2009 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	CNG and LPG vehicle subsidy: $500 dual and $1000 dedicated (nominal $), 1998-2009	Ensign fuel and vehicle subsidies decline with 3% inflation
No Transitional Barriers (Long-Run) - Higher LPG Costs	Existing programs (Note 1)	Existing (Note 2)	Current law, including CAFE, for alternative fuels. (Note 3)	None	The long-run analysis assumes: full vehicle model diversity, no cost of limited retail fuel availability, full scale fuel and vehicle production costs.

Case Name	Assumptions				
	Fleet program	**Fuel Taxes**	**Fuel Economy Credits**	**Other Alternative Fuel or Vehicle Policies**	**Comments**
Base	Local and Private Rule (Note 4)	Existing (Note 2)	Current law, including CAFE, for alternative fuels. (Note 3)	None	All of the following scenarios use these Base assumptions unless specifically noted otherwise.
Local and Private Rule with 50% Fuel Mandate	Local and Private Rule (Note 4). Plus 50% AF use requirement for fleet AFVs.	Existing (Note 2)	Current law, including CAFE, for alternative fuels. (Note 3)	None	In this scenarios, fleets are subject to the Local and Private Rule, and in addition, fleet AFVs are required to use at least 50% alternative fuel.
Continued Ethanol Tax Credit	Local and Private Rule (Note 4)	Existing nominal ethanol subsidy continues indefinitely (phased down after 2007)	Current law, including CAFE, for alternative fuels. (Note 3)	None	The $0.54 per physical gallon ethanol subsidy is worth $0.68 per GGE for E85 and continues to be available through the model's time horizon.
Low-GHG Fuel Subsidy	Local and Private Rule (Note 4)	Low-GHG fuel subsidies, declining with inflation (Note 5)	Current law, including CAFE, for alternative fuels. (Note 3)	None.	The $0.54 per physical gallon ethanol subsidy is worth $0.68 per GGE for E85 made from biomass. Not shown in the fuel use graph is the changing mix of E85 from corn to biomass through time.
Increased CAFE Standards	Local and Private Rule (Note 4)	Existing (Note 2)	Current law for Alternative fuels, new CAFE standards	CAFE standard increased 1 MPG, assume no change in conventional vehicle fleet	CAFE credit values unchanged from the base case, but dedicated and FFVs accumulate credits up until 5.5% and 11% of new vehicle sales in each year.
Ensign Bill: $0.50 AF credit thru 2004	Local and Private Rule (Note 4)	$0.50/GGE (nominal) alt fuel tax credit from 1998-2004 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	None.	Ensign fuel subsidies decline with 3% inflation

Case Name	Assumptions				
	Fleet program	**Fuel Taxes**	**Fuel Economy Credits**	**Other Alternative Fuel or Vehicle Policies**	**Comments**
Extended Ensign Bill: $0.25 AF credit thru 2009	Local and Private Rule (Note 4)	$0.25/GGE (nominal) alt fuel tax credit from 1998-2009 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)None.	Ensign fuel subsidies decline with 3% inflation	
Ensign Bill: $0.50 AF credit and AFV Credits thru 2004	Local and Private Rule (Note 4)	$0.50/GGE (nominal) alt fuel tax credit from 1998-2004 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	CNG and LPG vehicle subsidy: $500 dual and $1000 dedicated (nominal $), 1998-2004	Ensign fuel and vehicle subsidies decline with 3% inflation
Extended Ensign Bill: $0.25 AF credit and AFV Credits thru 2009	Local and Private Rule (Note 4).	$0.25/GGE (nominal) alt fuel tax credit from 1998-2009 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	CNG and LPG vehicle subsidy: $500 dual and $1000 dedicated (nominal $), 1998-2009	Ensign fuel and vehicle subsidies decline with 3% inflation
Extended Ensign Bill: $0.50 AF credit thru 2009	Local and Private Rule (Note 4).	$0.50/GGE (nominal) alt fuel tax credit from 1998-2009 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	CNG and LPG vehicle subsidy: $500 dual and $1000 dedicated (nominal $), 1998-2009	Ensign fuel and vehicle subsidies decline with 3% inflation
Extended Ensign Bill: $0.50 AF credit and AFV Credits thru 2009	Local and Private Rule (Note 4).	$0.50/GGE (nominal) alt fuel tax credit from 1998-2009 (excluding E85 and Electricity)	Current law, including CAFE, for alternative fuels. (Note 3)	CNG and LPG vehicle subsidy: $500 dual and $1000 dedicated (nominal $), 1998-2009	Ensign fuel and vehicle subsidies decline with 3% inflation

1. Existing programs only - no private fleet mandates. See Figure 9

2. Under existing tax scenario, the ethanol subsidy expires on 1/1/2008, and declines slightly in nominal terms between now and then, see Table 1. Subsidy in real (constant) $ declines with 3% inflation. Standard (Federal Highway Fund and state) motor fuel.

3. Our estimate of CAFE credit values: FFVs and dedicated vehicles receive $343 and $686 per vehicle, respectively. Dedicated and FFVs accumulate credits up until 0.5% and 1% new vehicles sales in each year. The CAFE credits for FFVs expire after model year 2004.

4. Private fleet are required to purchase AFVs under the EPACT "Local and Private Rulemaking" authority. The magnitude of this program over time is shown in Figure 12.

5. Low-GHG fuel subsidies: Beginning 2001, $0.54 per physical gallon ethanol subsidy ends, replaced by subsidy (tax reduction) for low GHG fuels. Cellulosic ethanol, viewed as having near-zero GHG emissions,

Appendix 2: Technical Assumptions

Table 21: Conversion Factors Used the TAFV Model
(based on higher heating values)

1 Barrel	=	42	U.S. Gallons
1 BBL LPG	=	4.011	MMBTU
1 BBL M85	=	3.020	MMBTU
1 BBL M100	=	2.626	MMBTU
1 BBL Gasoline	=	5.253	MMBTU
1 BBL E85	=	3.794	MMBTU
1 BBL E100	=	3.536	MMBTU
MCF CNG	=	1.030	MMBTU
Gasoline Vehicle	=	1.00	Efficiency
Dedicated M85 Vehicle	=	1.05	Efficiency
FFV M85 Vehicle	=	1.01	Efficiency
Dedicated E85 Vehicle	=	1.05	Efficiency
FFV E85 Vehicle	=	1.01	Efficiency
Dedicated/Dual CNG	=	1.00	Efficiency
Dedicated/Dual LPG	=	1.00	Efficiency
Electric Vehicle	=	4.29	Efficiency

Table 22: Greenhouse Gas Emissions, kg per GGE, Year 2000

Feedstock	Gasoline	Natural Gas			Biomass	Corn	Mix
Fuel-Vehicle Combination	Gasoline	M85	LPG	CNG	E85	E85	EV
Vehicle Operations	10.085	9.236	9.578	8.758	2.335	2.335	0.000
Fuel Production and Distribution	2.653	3.116	1.592	2.619	-1.342	6.396	8.211
Vehicle Manufacture	1.575	1.619	1.679	1.824	1.626	1.626	1.507
Total Life Cycle	14.314	13.970	12.849	13.200	2.619	10.357	9.718

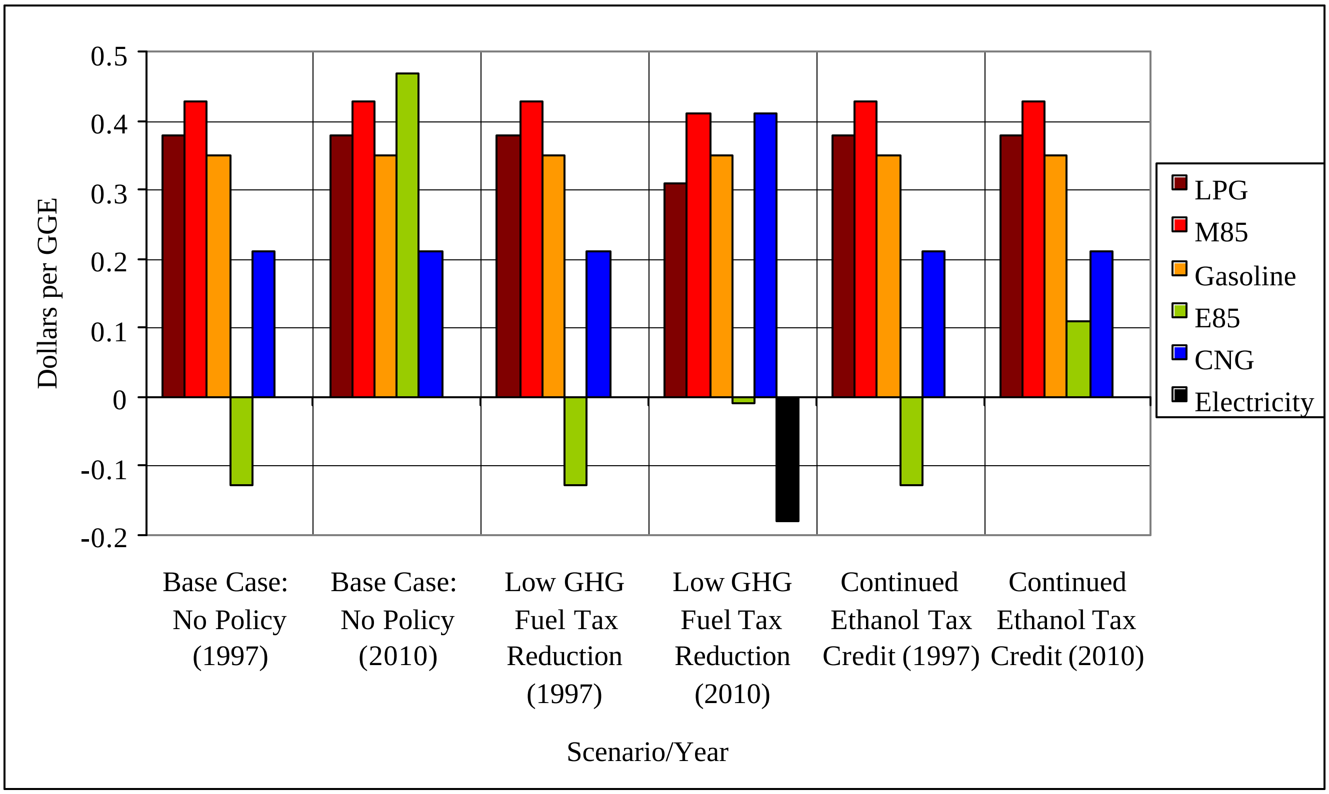
Source: M. Wang (1999) GREET Model Version 1.4. For summary see Taxes16.xls, 07/12/99.

Table 23: Tax Comparison Across Policies ($94/GGE)

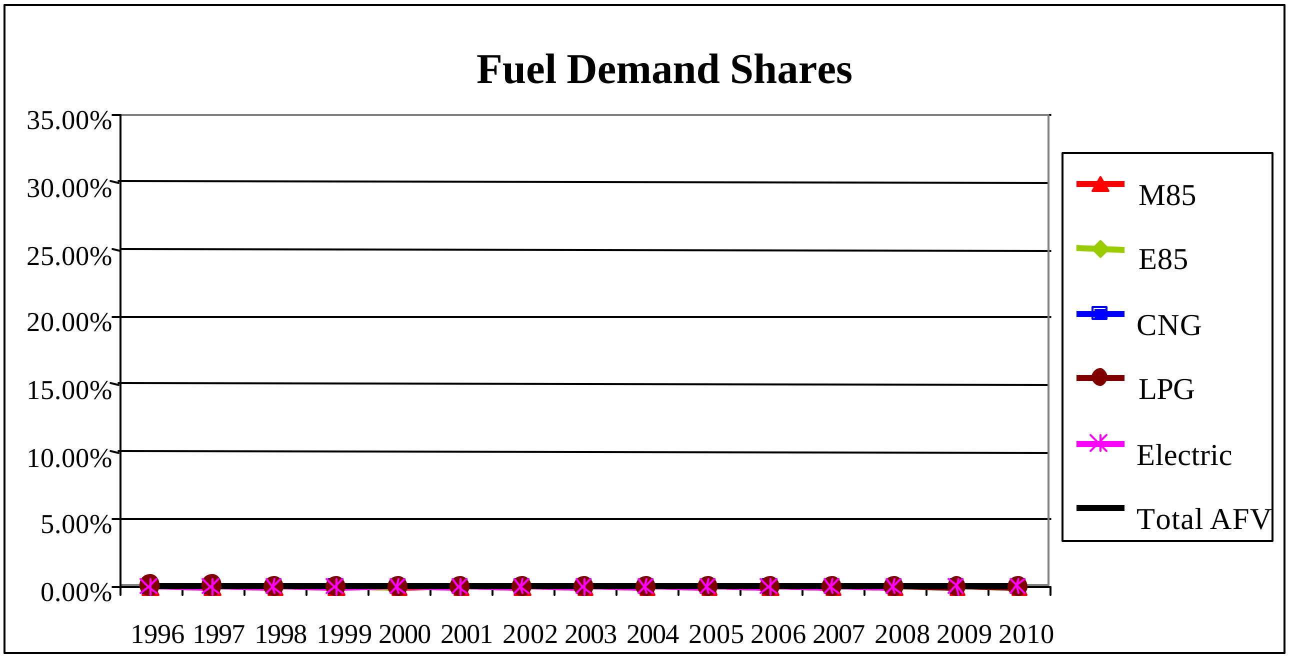
Fuel	Base Case: No Policy		Low GHG Fuel Tax Reduction		Continued Ethanol Tax Credit	
Year	1997	2010	1997	2010	1997	2010
LPG	0.38	0.38	0.38	0.31	0.38	0.38
M85	0.43	0.43	0.43	0.41	0.43	0.43
Gasoline	0.35	0.35	0.35	0.35	0.35	0.35
E85	-0.13	0.47	-0.13	-0.01	-0.13	0.11
CNG	0.21	0.21	0.21	0.16	0.21	0.21
Electricity	0	0	0	-0.18	0.00	0.00

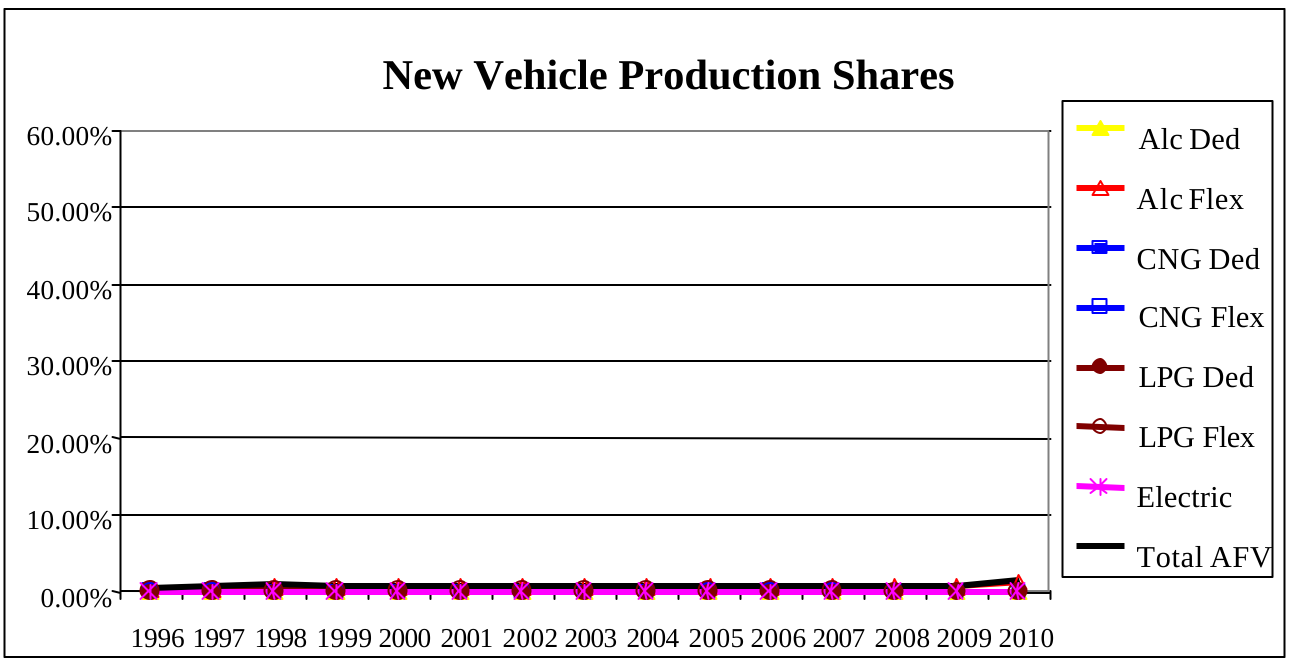
Source: Taxes16.xls

Figure 17: Comparison of Motor Fuel Taxes Across Scenarios



Appendix 3 - Result Graphs

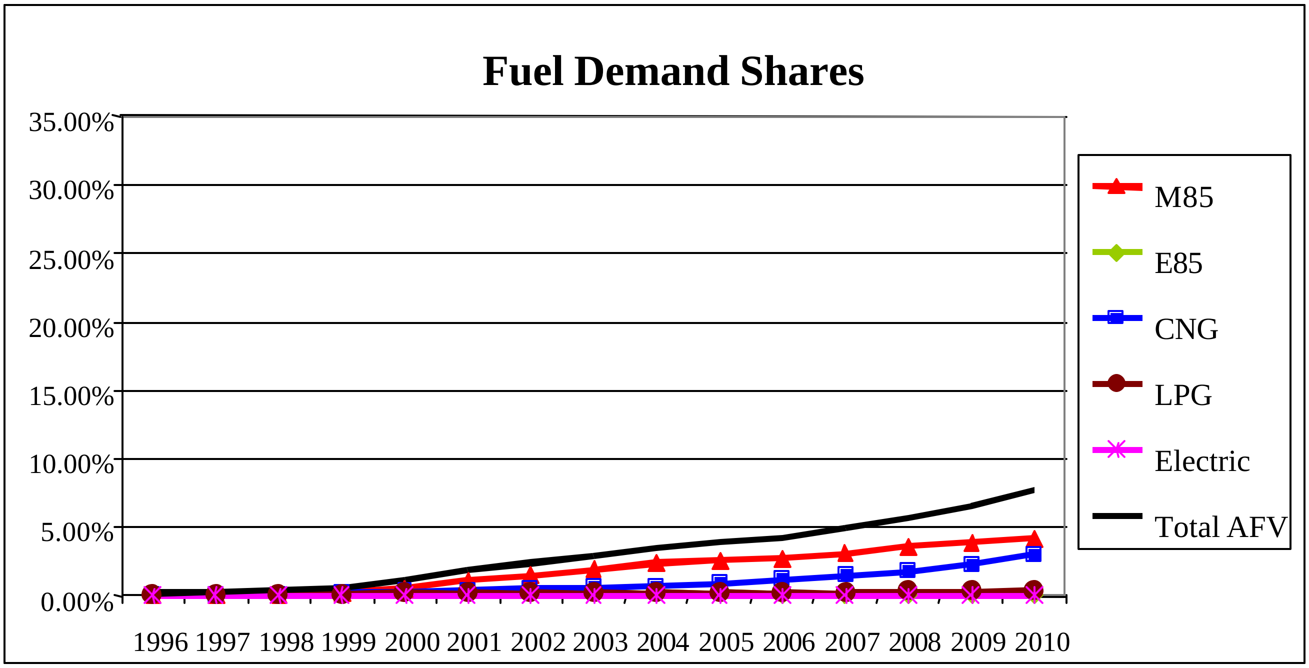


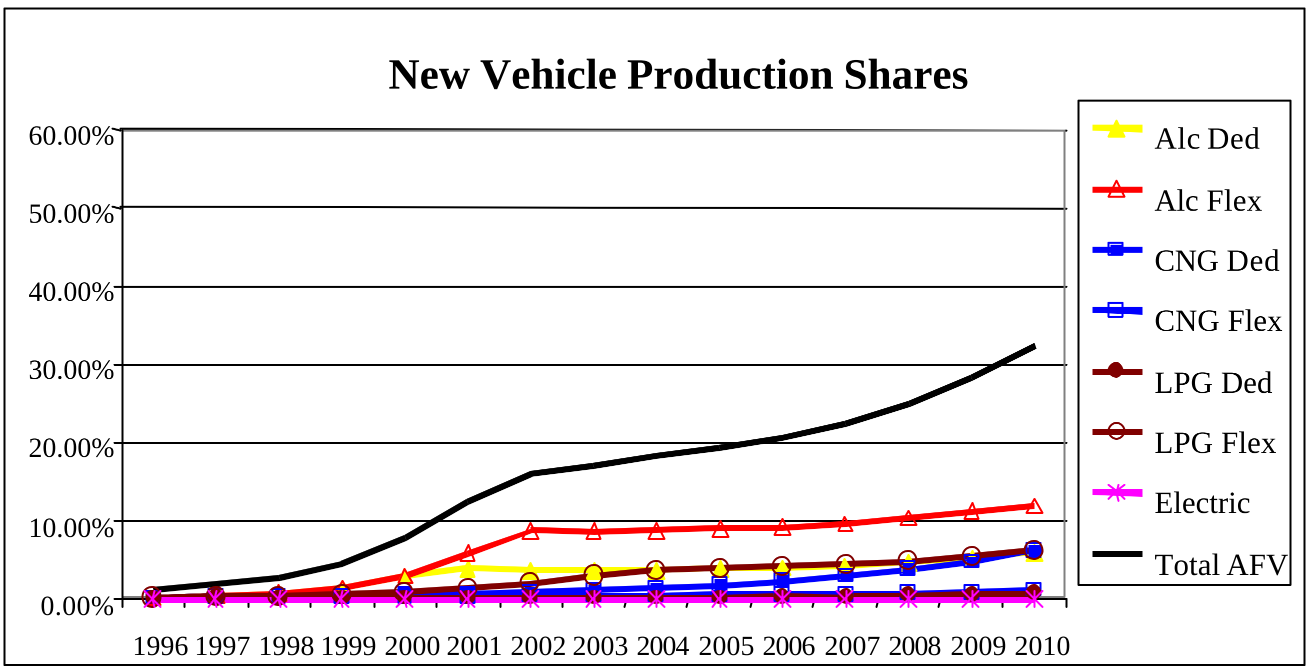


Case #1, R97B00RS

AEO Base, Higher LPG Cost

Figure 18: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost
Policy: Base-No New Policy Case

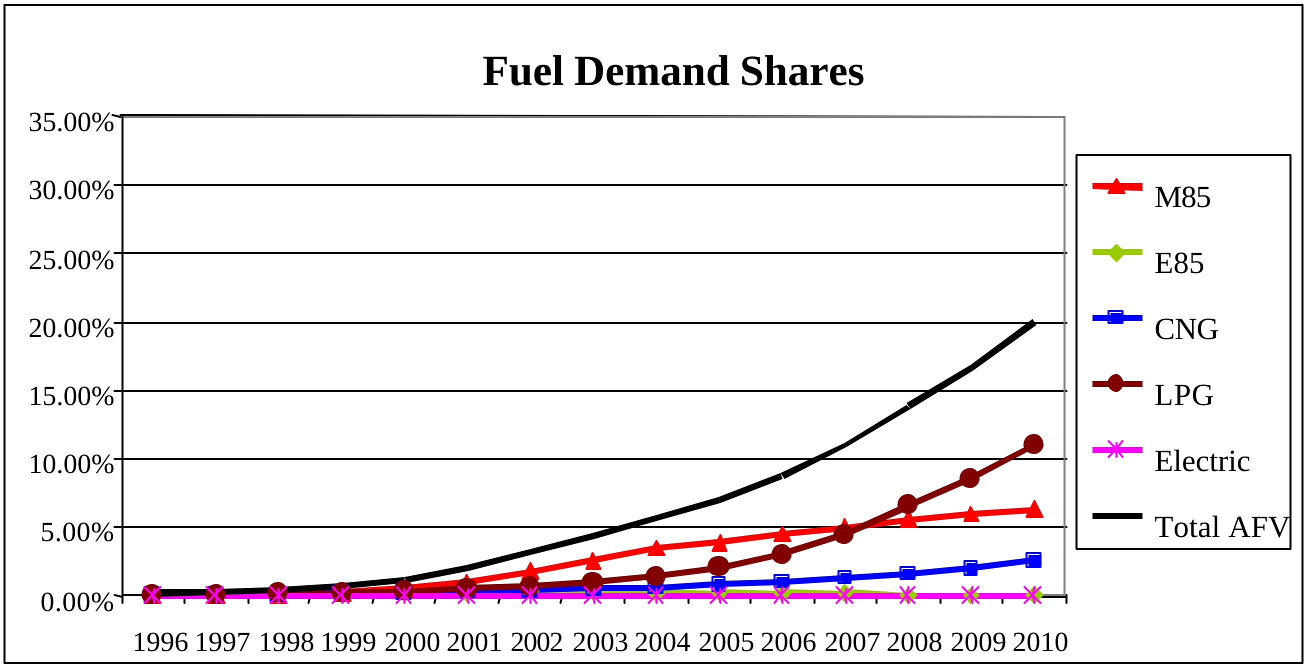


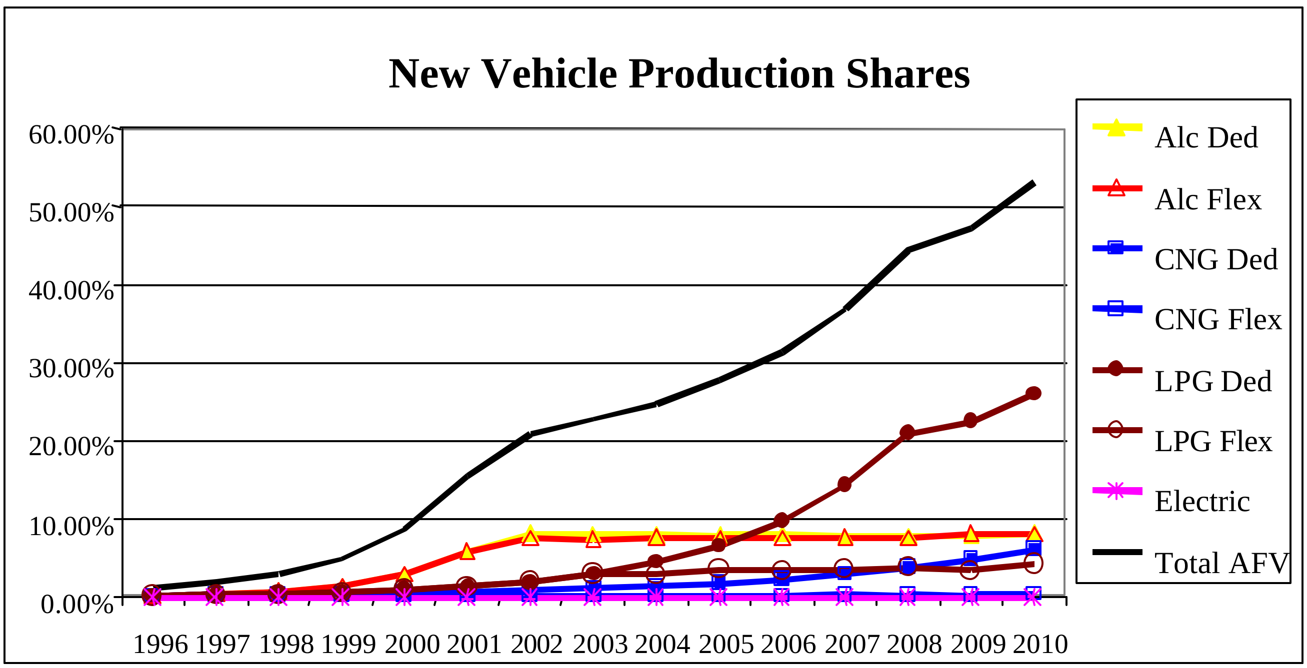


Case #12, R97BNBRS

AEO Base, Higher LPG Cost

Figure 19: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost
Policy: No Transitional Barriers

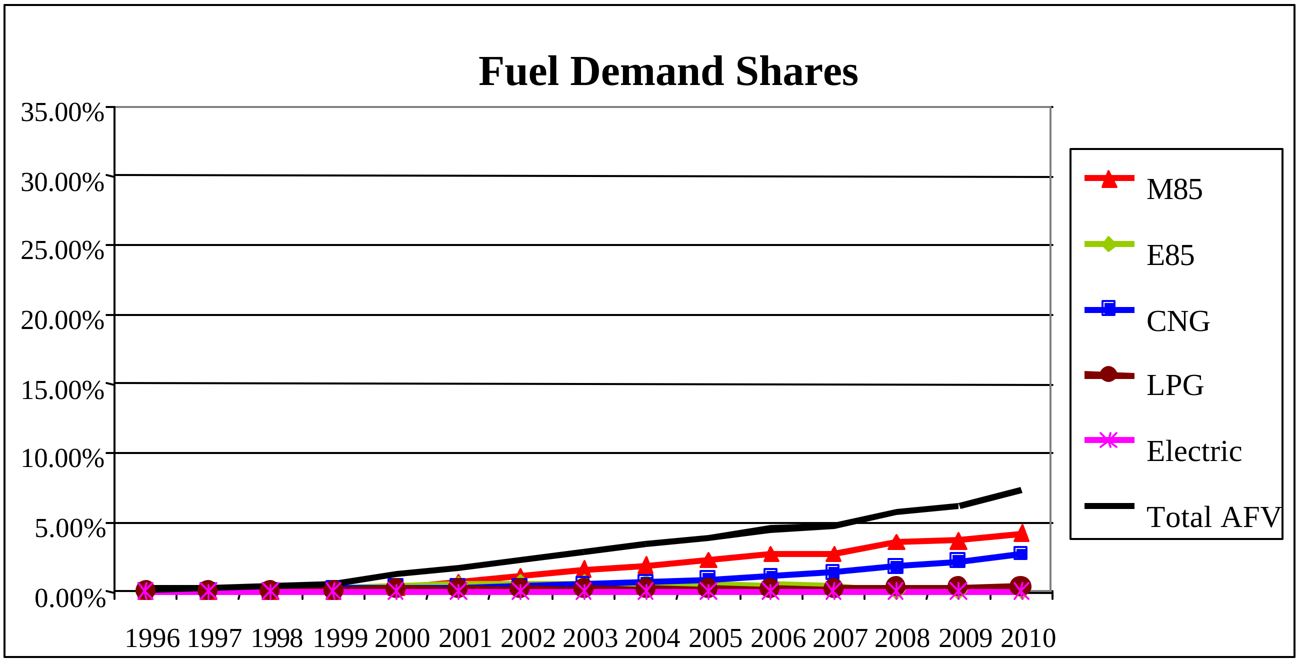


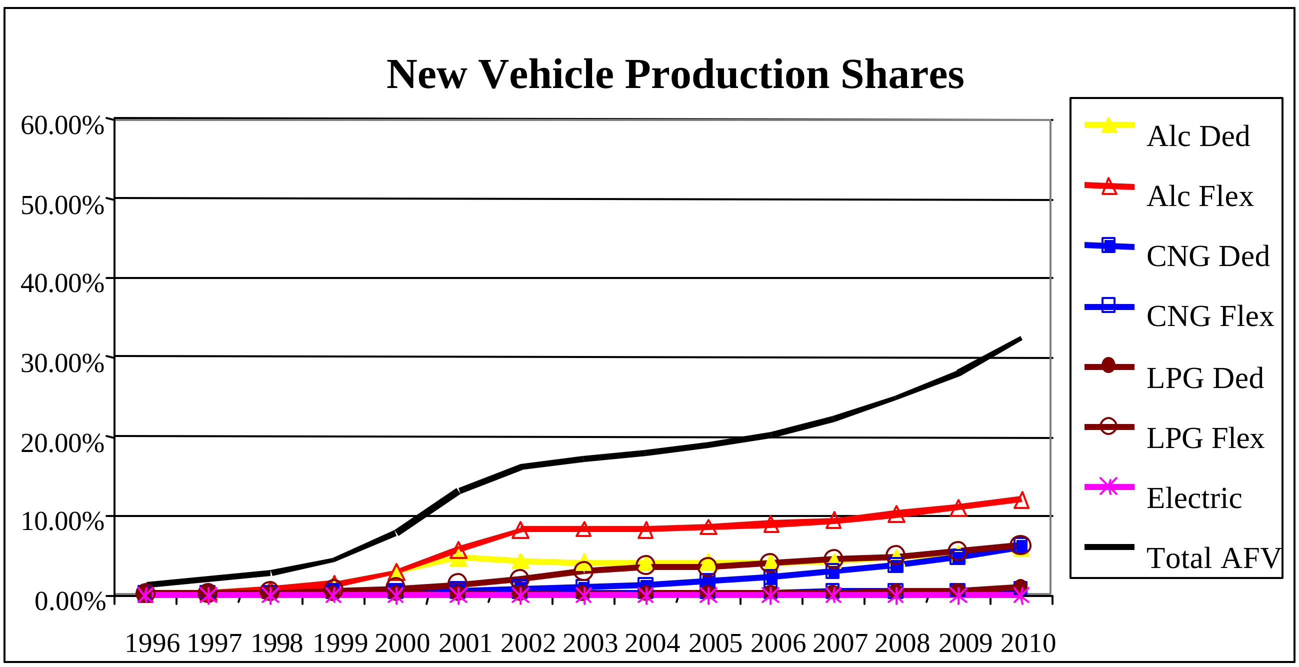


Case #48, R97BNBRS

AEO HWOP, Lower LPG Cost

Figure 20: Fuel Demand and New Vehicle Production Shares
Scenario: Higher World Oil Price, Lower LPG Cost
Policy: No Transitional Barriers

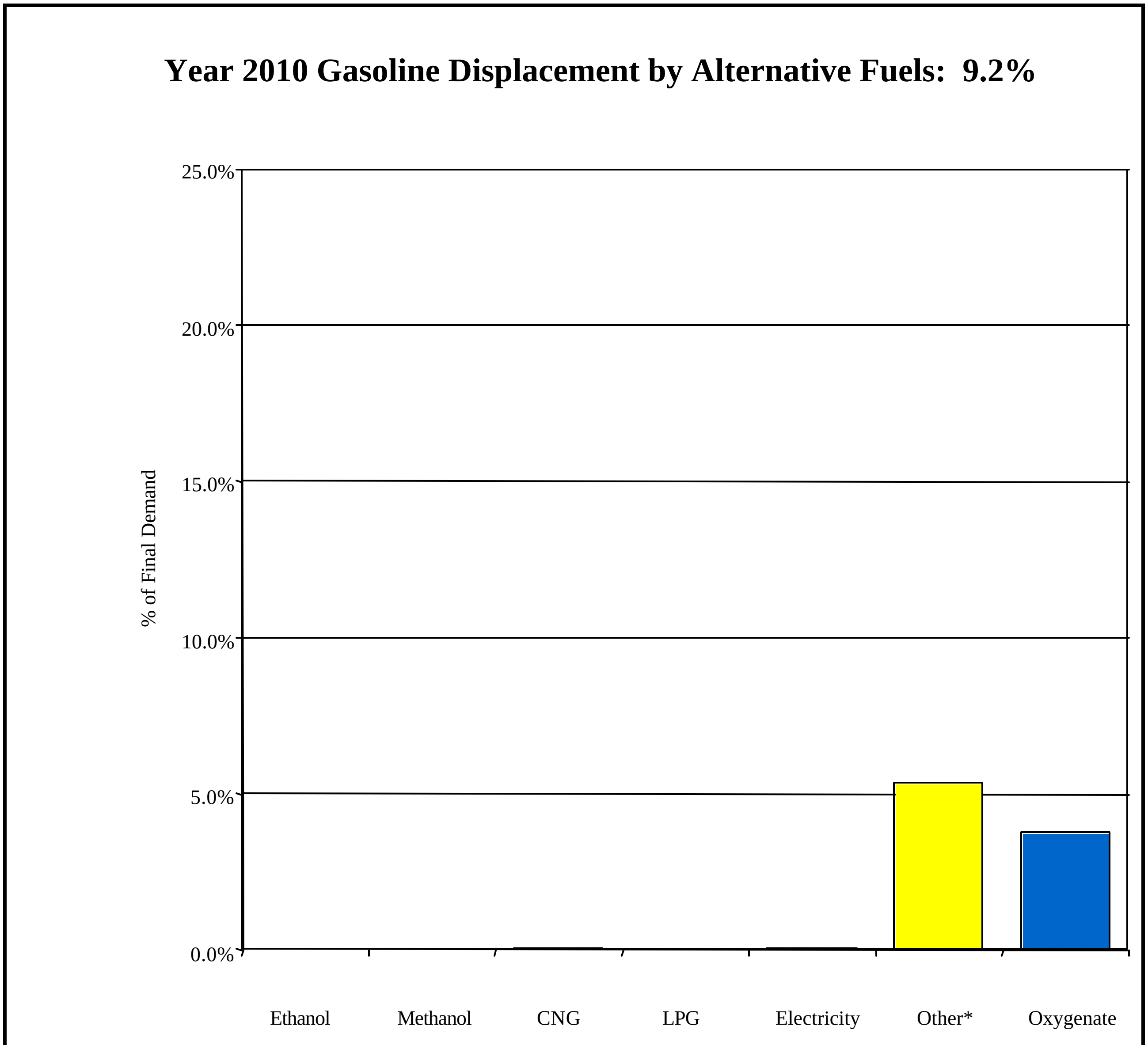




Case #72, R97BNBRS

AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted

Figure 21: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted
Policy: No Transitional Barriers



	Ethanol	Methanol	CNG	LPG	Electricity	Other*	Oxygenate
Quantity (MMBGED)	0.00	0.00	0.00	0.00	0.00	0.51	0.36
Share	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	3.8%

*Includes Natural Gas Liquids, Other Hydrocarbons, and Hydrogen

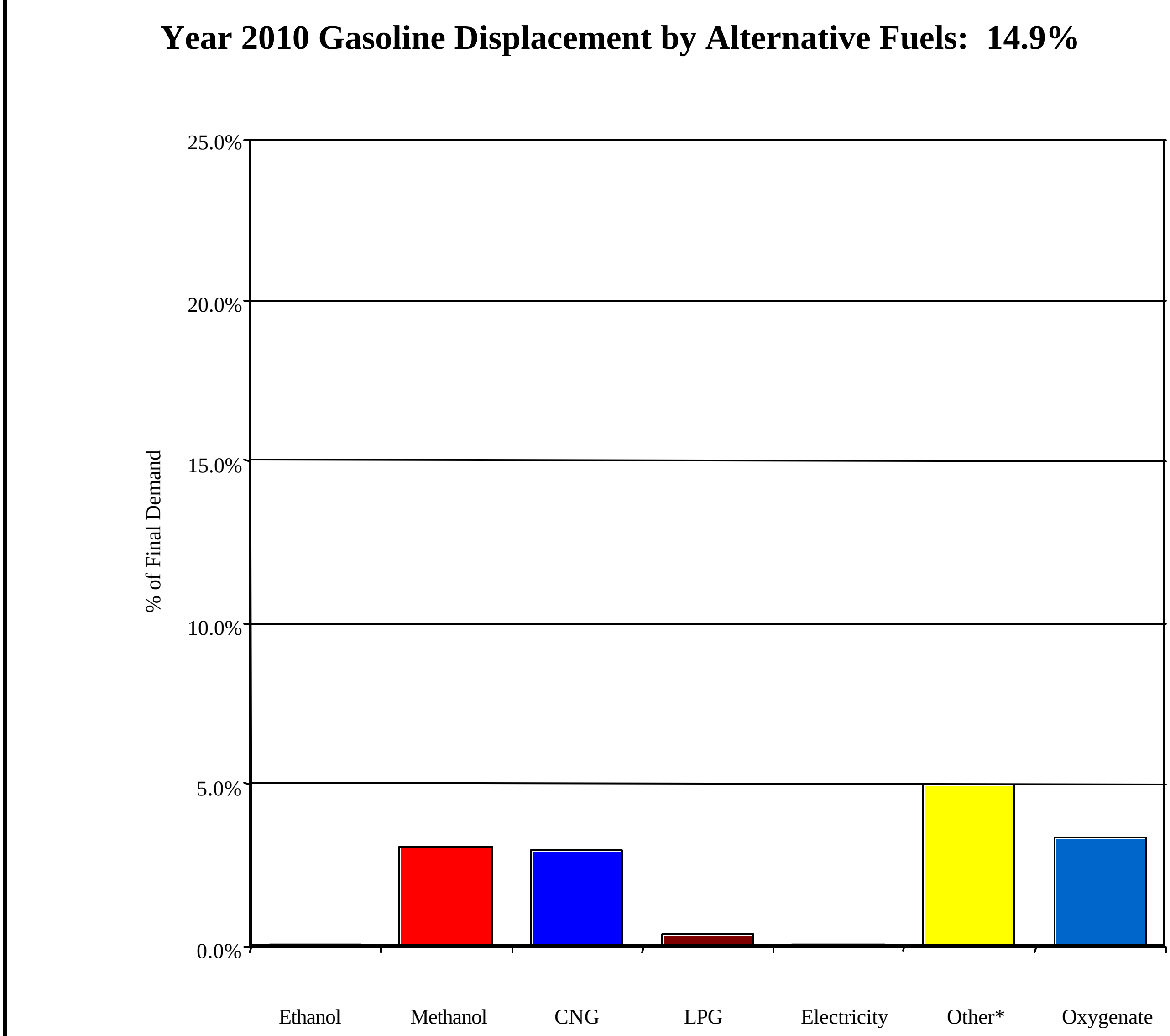
Case #1, R97B00RS

AEO Base, Higher LPG Cost

Figure 22: Gasoline Displacement

Scenario: AEO Base, Higher LPG Cost

Policy: Base-No New Policy Case

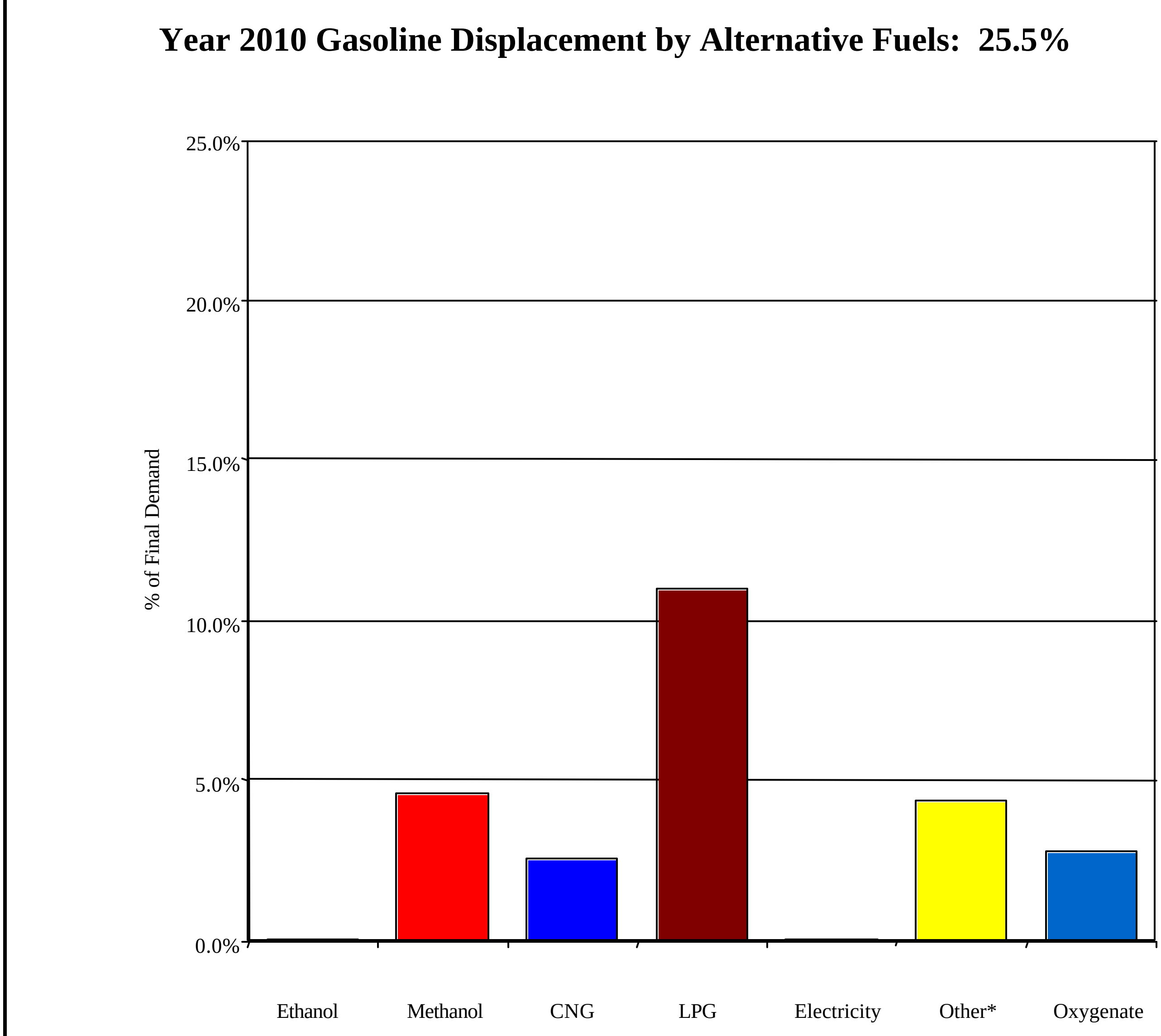


	Ethanol	Methanol	CNG	LPG	Electricity	Other*	Oxygenate
Quantity (MMBGED)	0.00	0.30	0.29	0.04	0.00	0.48	0.32
Share	0.0%	3.1%	3.0%	0.4%	0.0%	5.0%	3.4%

*Includes Natural Gas Liquids, Other Hydrocarbons, and Hydrogen

Case #12, R97BNBRS
AEO Base, Higher LPG Cost

Figure 23: Gasoline Displacement
Scenario: AEO Base, Higher LPG Cost
Policy No Transitional Barriers



	Ethanol	Methanol	CNG	LPG	Electricity	Other*	Oxygenate
Quantity (MMBGED)	0.00	0.45	0.25	1.05	0.00	0.42	0.27
Share	0.0%	4.6%	2.6%	11.0%	0.0%	4.4%	2.8%

*Includes Natural Gas Liquids, Other Hydrocarbons, and Hydrogen

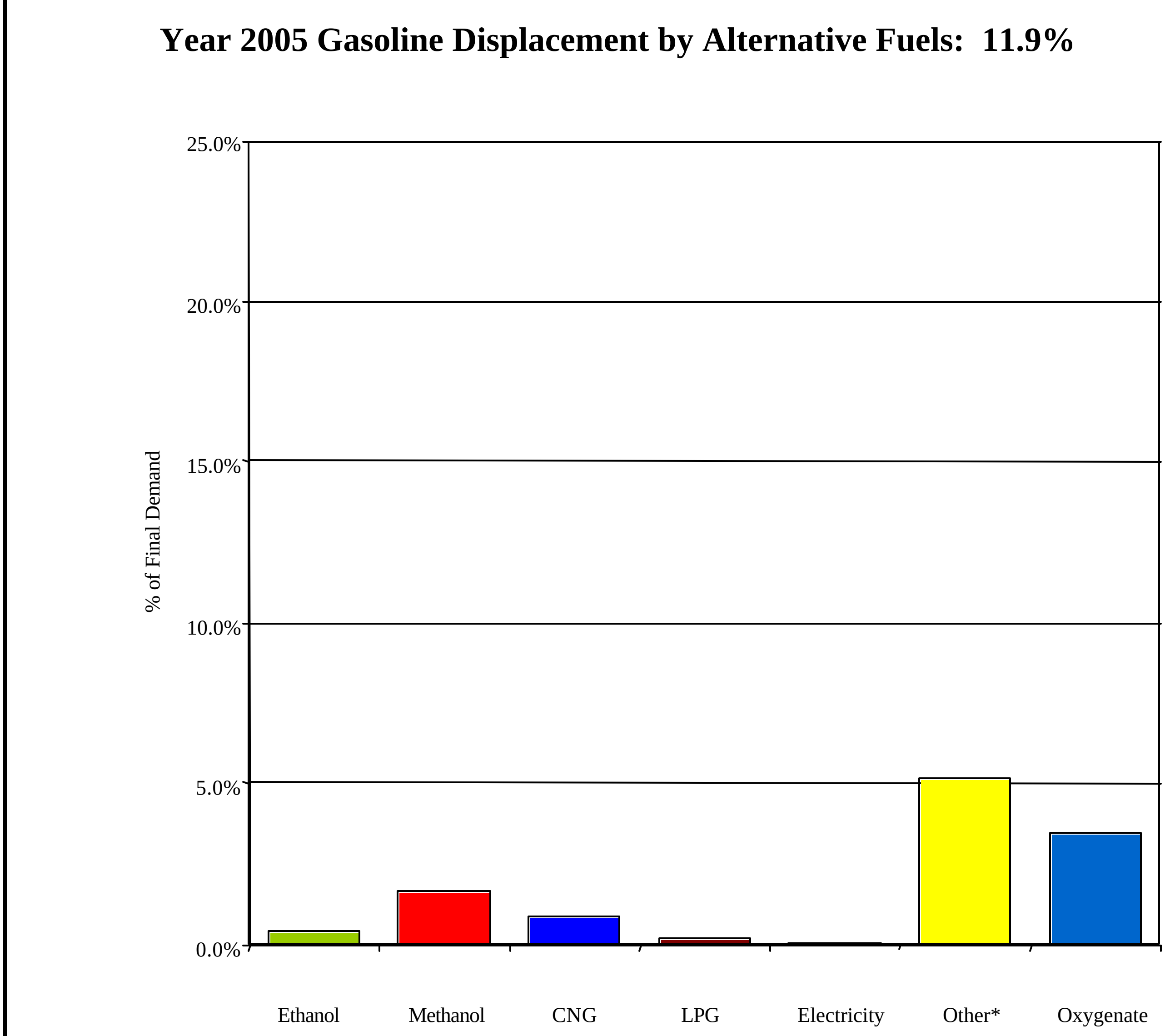
Case #48, R97BNBRS

AEO HWOP, Lower LPG Cost

Figure 24: Gasoline Displacement

Scenario: Higher World Oil Price, Lower LPG Cost

Policy: No Transitional Barriers



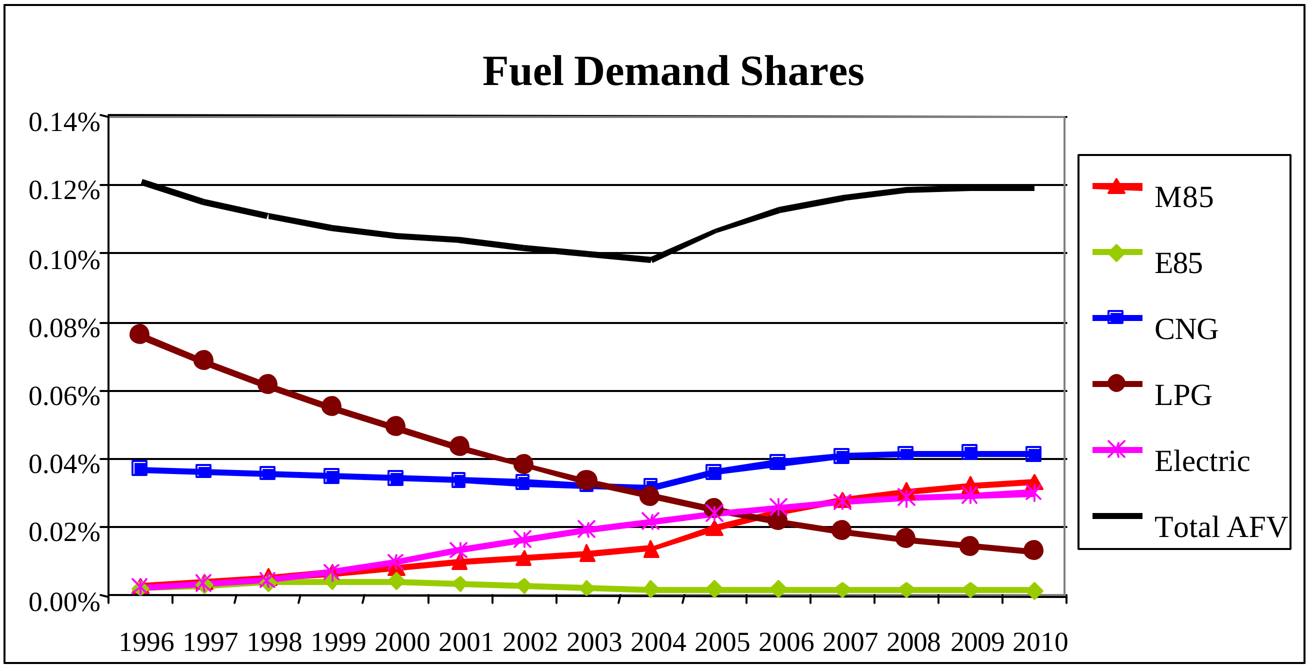
	Ethanol	Methanol	CNG	LPG	Electricity	Other*	Oxygenate
Quantity (MMBGED)	0.04	0.15	0.08	0.02	0.00	0.46	0.31
Share	0.4%	1.7%	0.9%	0.2%	0.0%	5.2%	3.5%

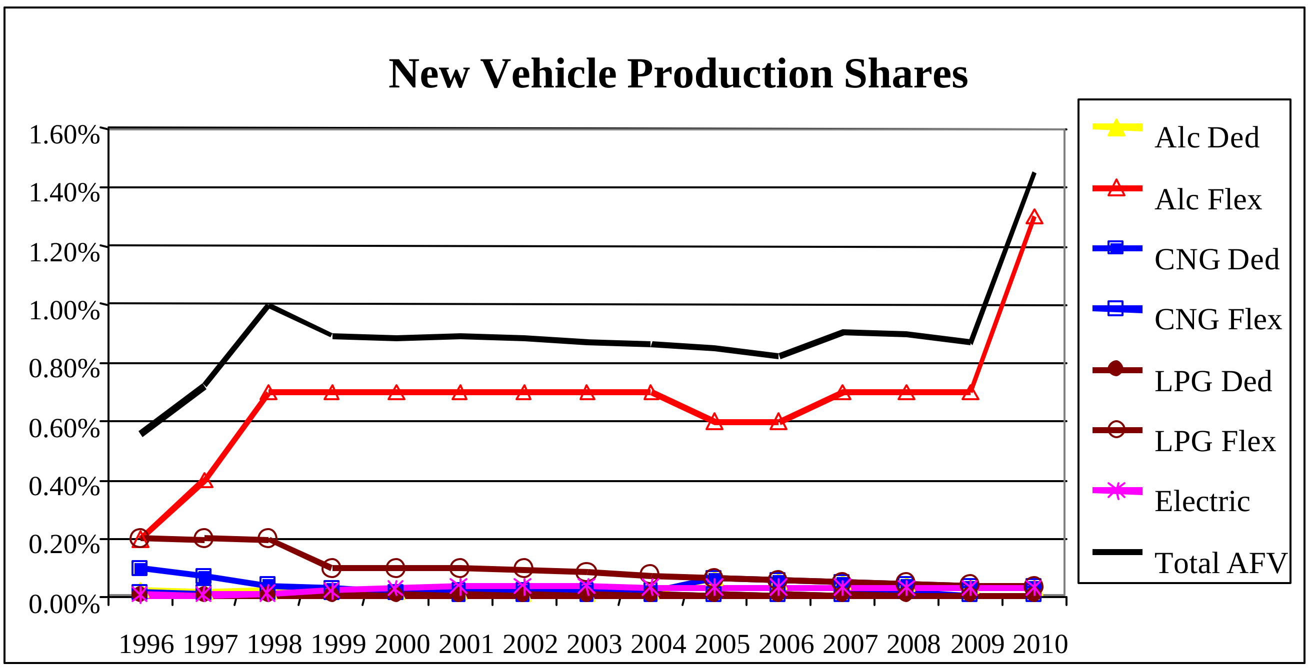
*Includes Natural Gas Liquids, Other Hydrocarbons, and Hydrogen

Case #72, R97BNBRS

AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted

Figure 25: Gasoline Displacement
Scenario: AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted
Policy: No Transitional Barriers

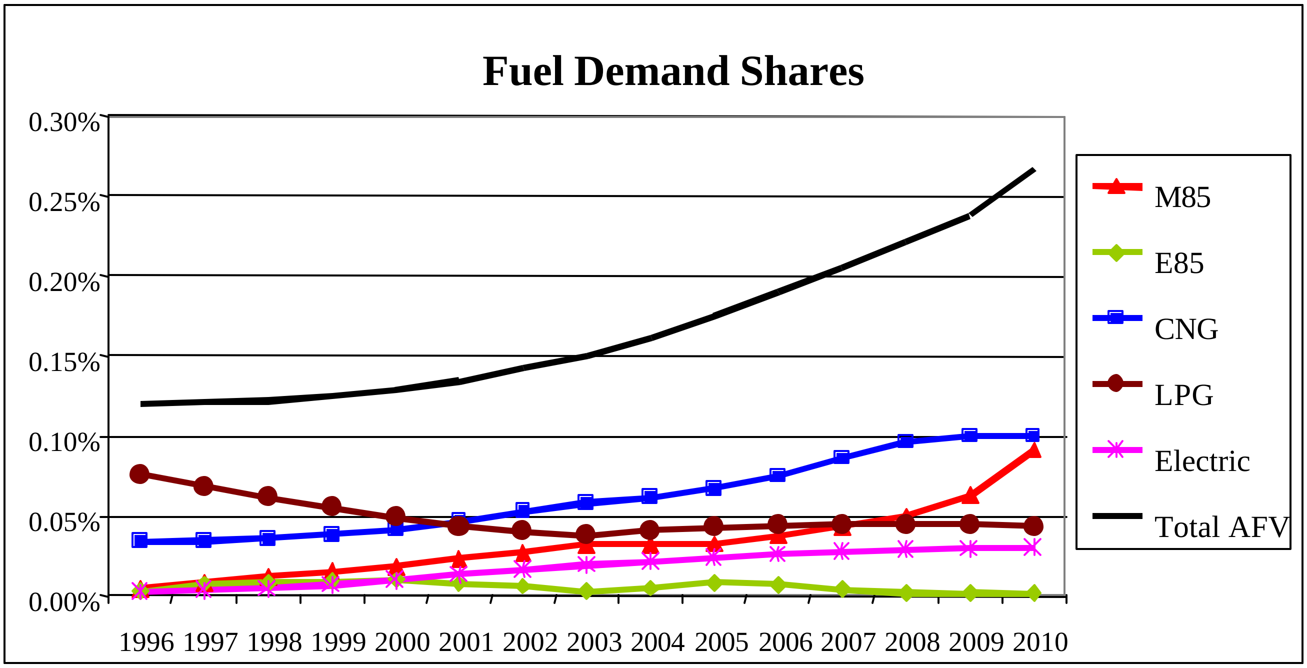


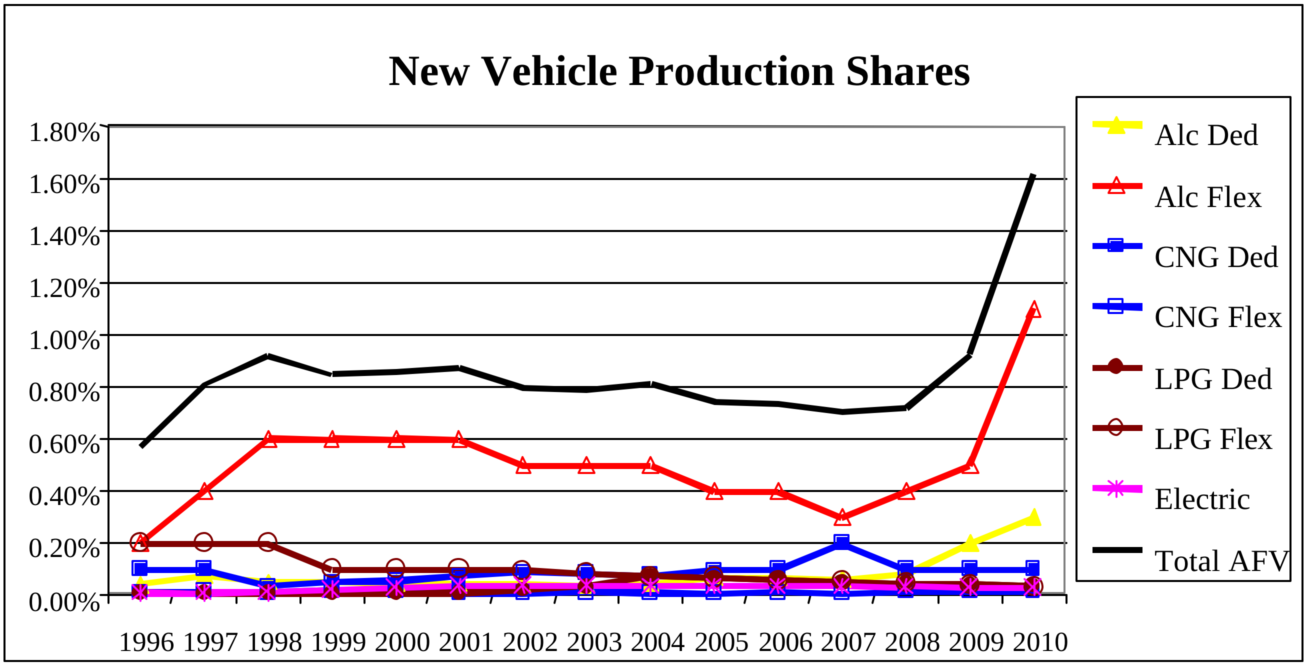


Case #1, R97B00RS

AEO Base, Higher LPG Cost

Figure 26: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost
Policy: Base-No New Policy Case
(Enhanced Scale)

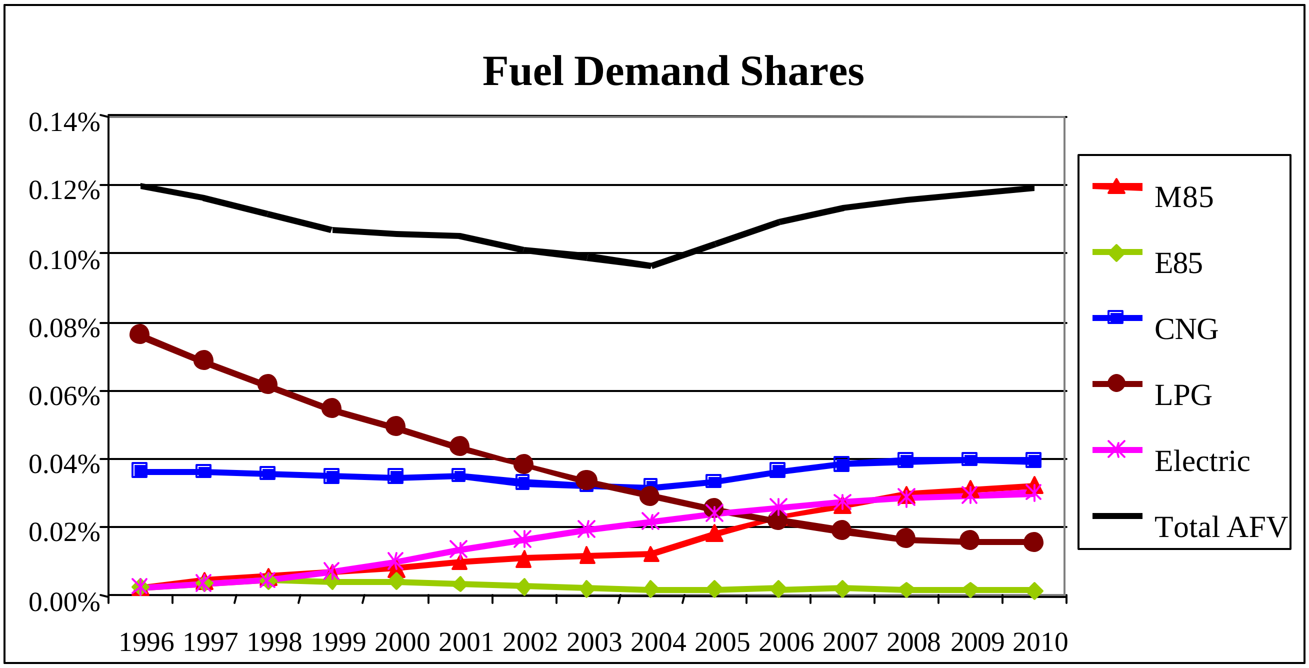


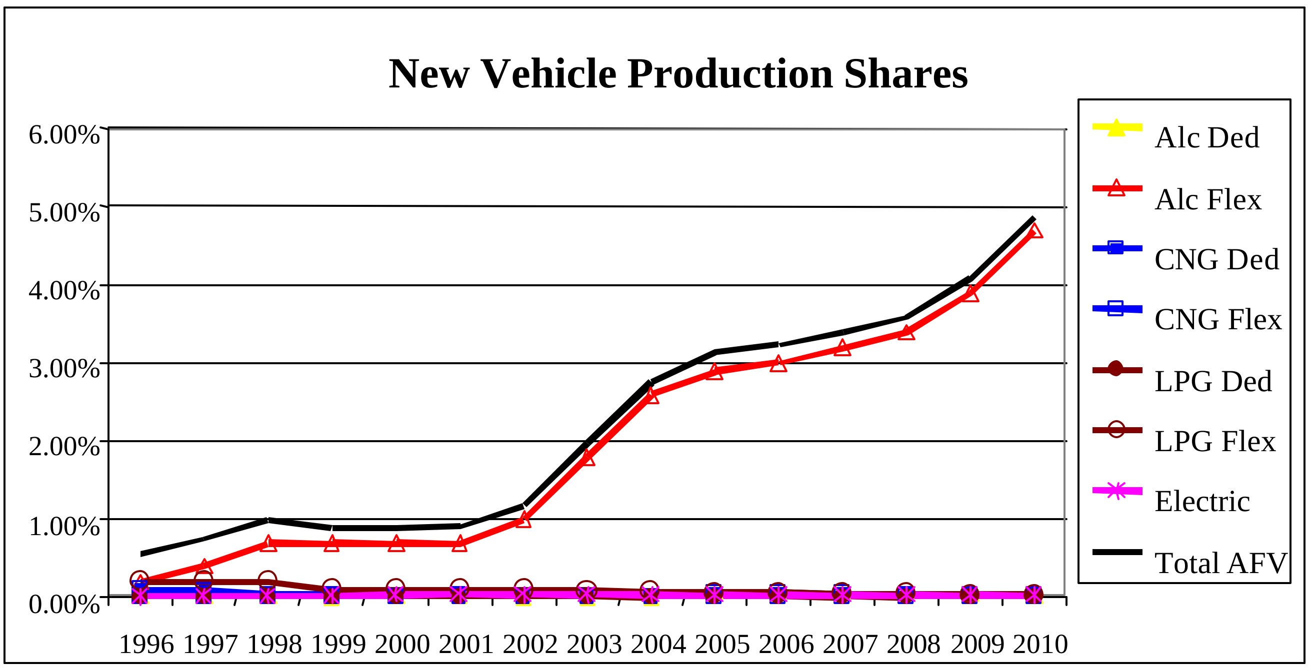


Case #37, R97B00RS

AEO HWOP, Lower LPG Cost

Figure 27: Fuel Demand and New Vehicle Production Shares
Scenario: Higher World Oil Price, Lower LPG Cost
Policy: Base-No New Policy Case
(Enhanced Scale)





Case #2, R97P00RS

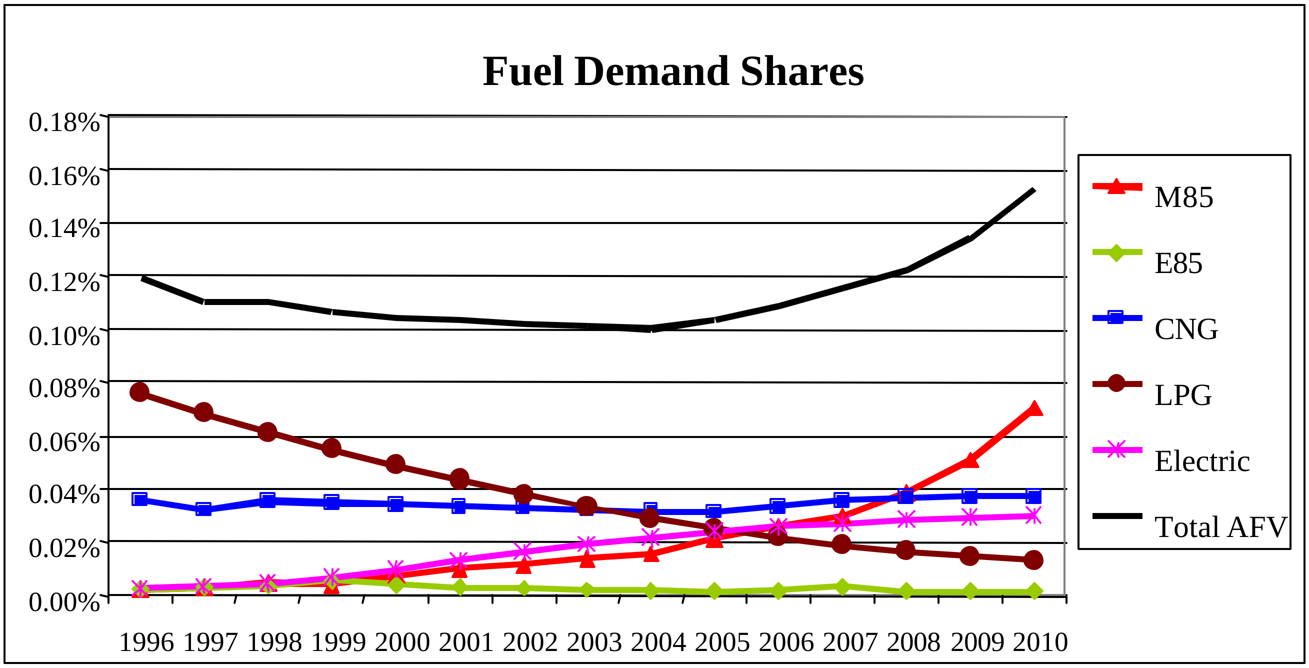
AEO Base, Higher LPG Cost

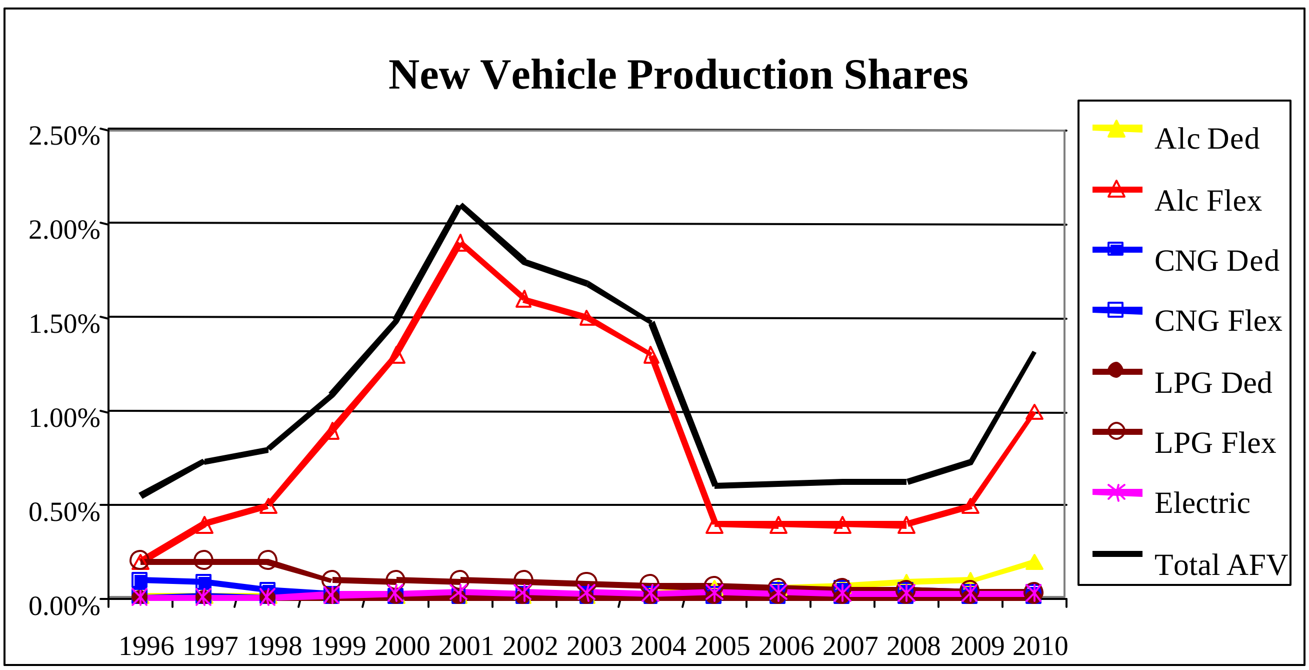
Figure 28: Fuel Demand and New Vehicle Production Shares

Scenario: AEO Base, Higher LPG Cost

Policy: Late Private Rule

(Enhanced Scale)

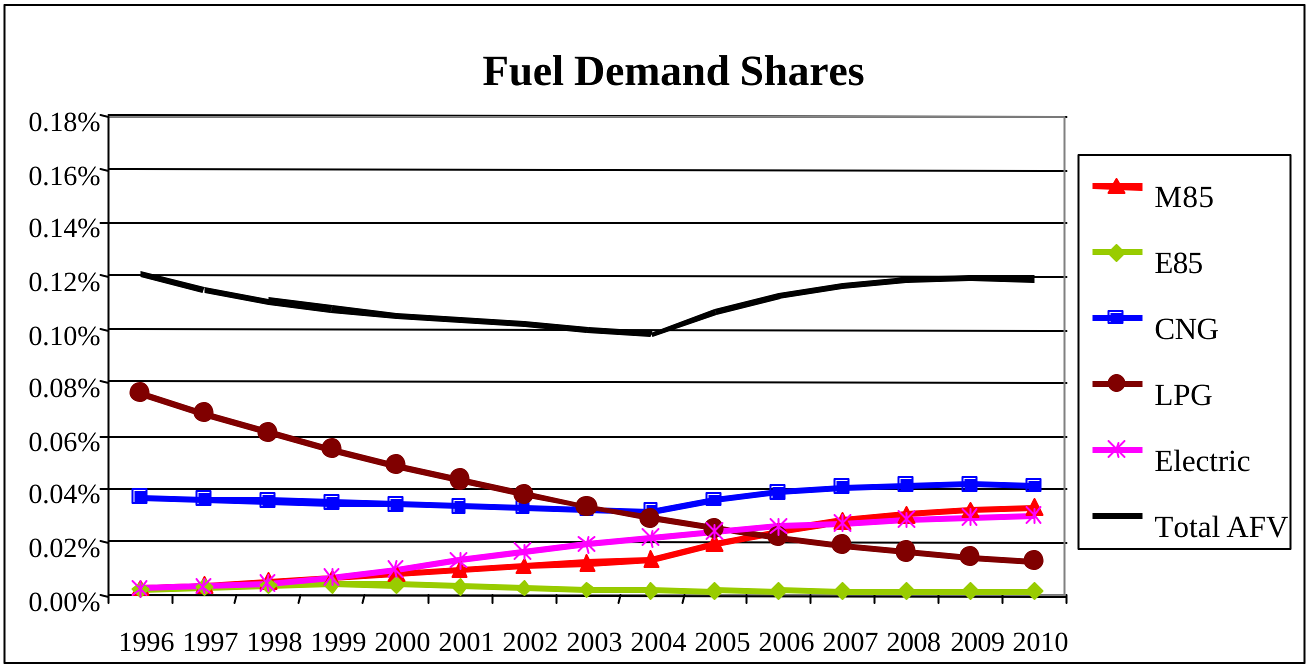


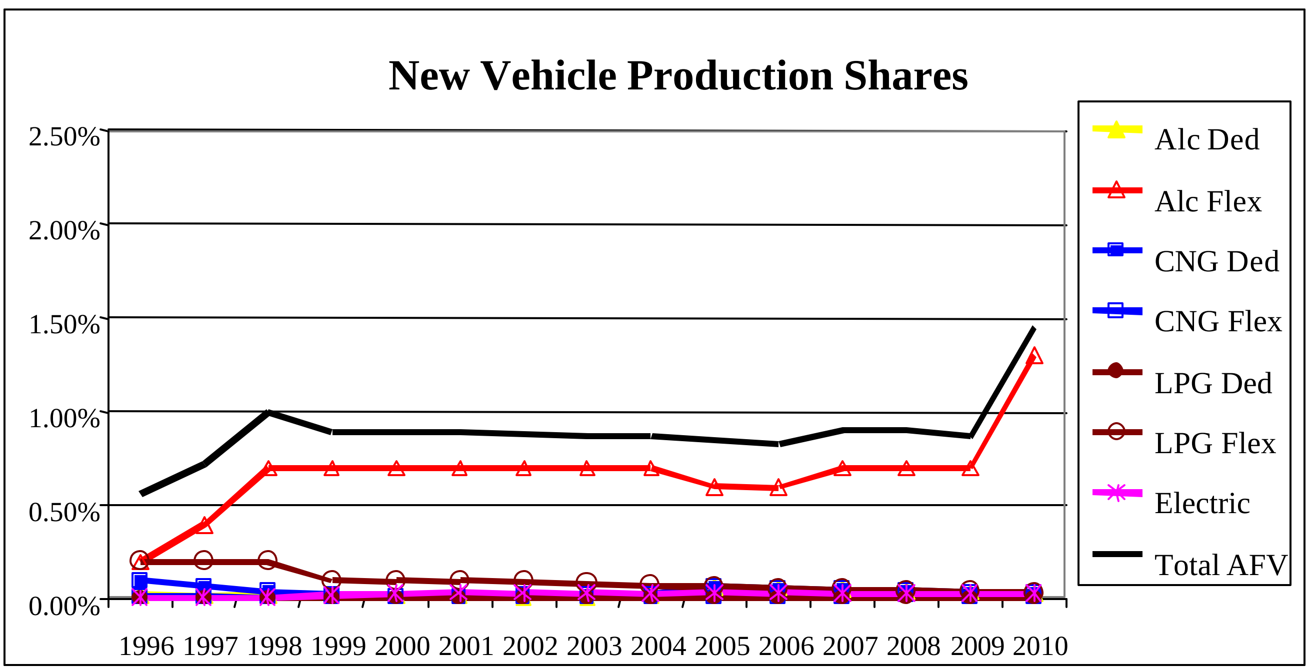


Case #6, R97CA0RS

AEO Base, Higher LPG Cost

Figure 29: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost
Policy: Increased CAFE Standards
(Enhanced Scale)

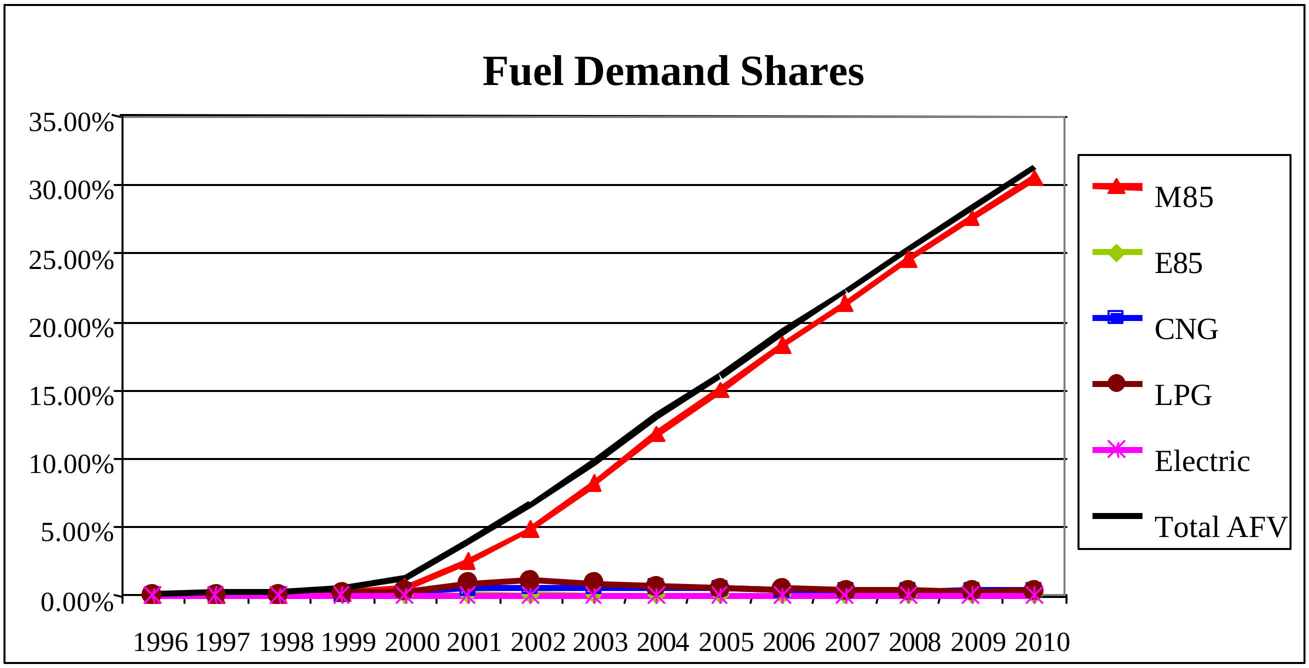


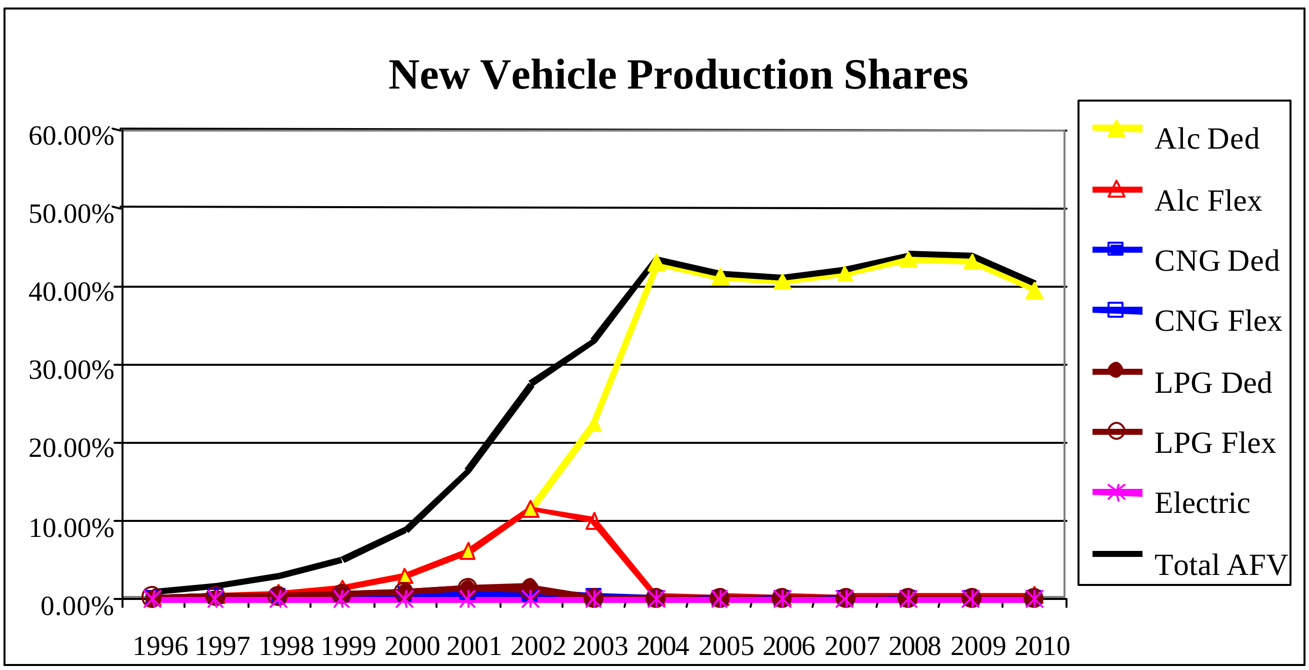


Case #1, R97B00RS

AEO Base, Higher LPG Cost

Figure 30: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost
Policy: Base-No New Policy Case
(Scale Matches Increased CAFE Standard)

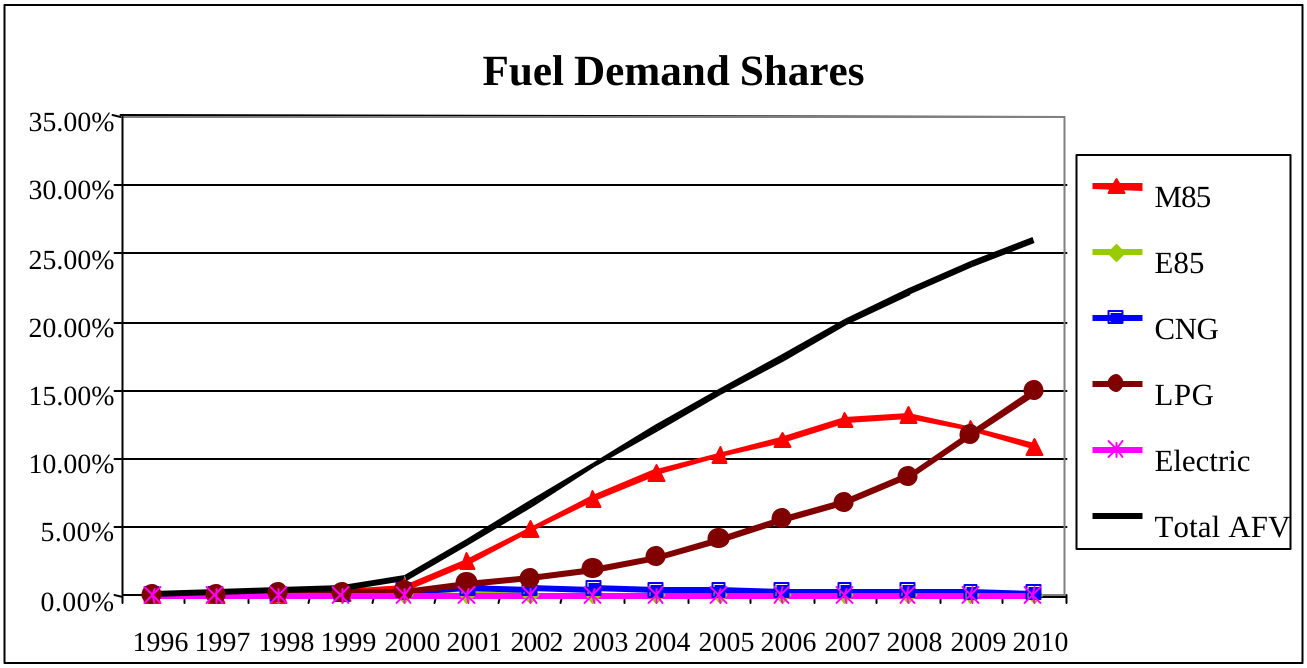


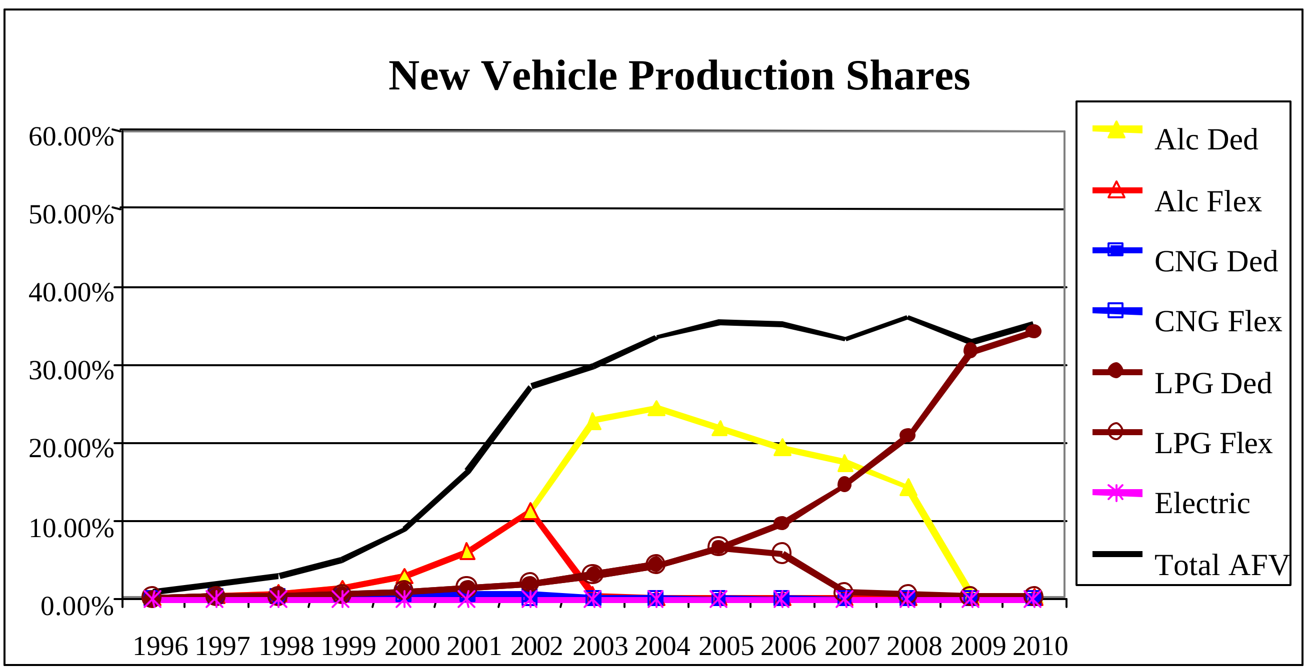


Case #7, R97FM0RS

AEO Base, Higher LPG Cost

Figure 31: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost
Policy: Retail Alternative Fuel Sales Mandate

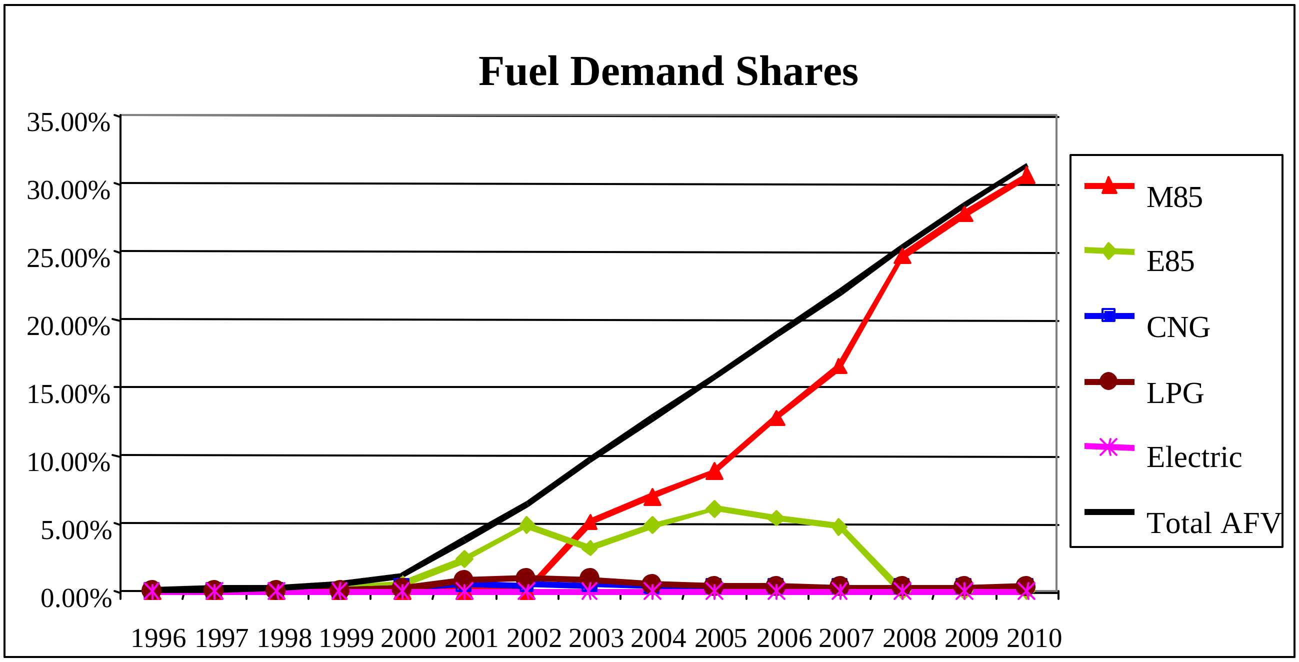


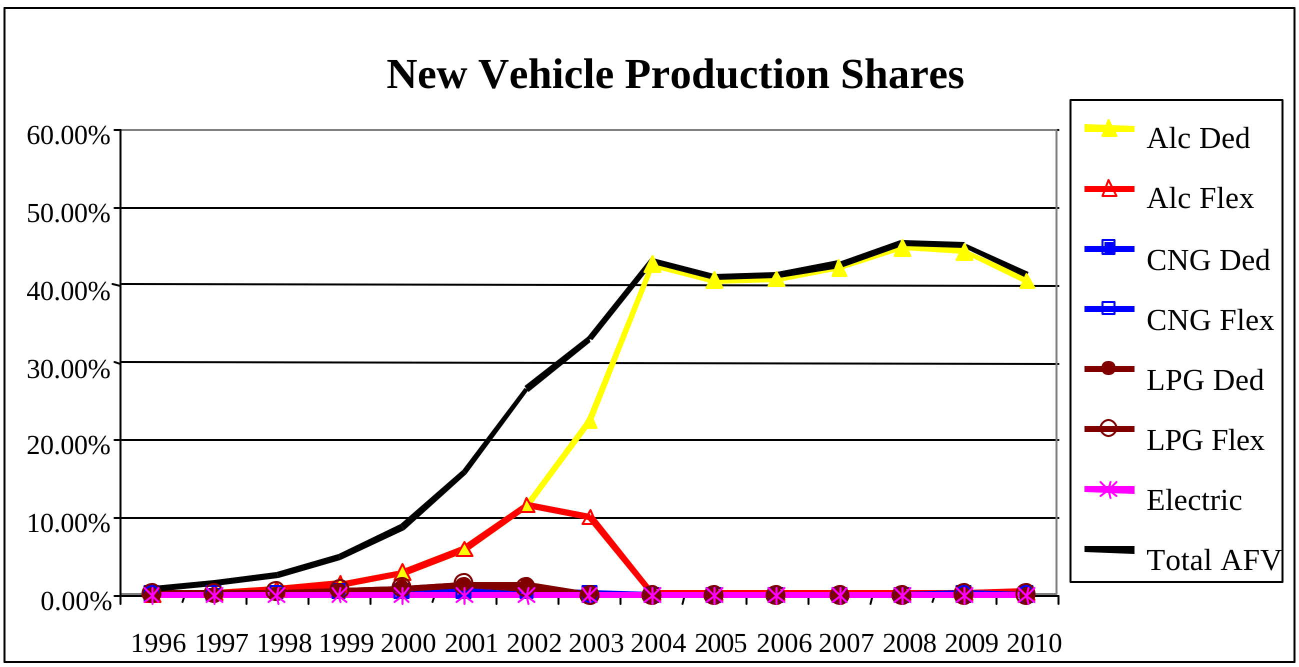


Case #43, R97FM0RS

AEO HWOP, Lower LPG Cost

Figure 32: Fuel Demand and New Vehicle Production Shares
Scenario: Higher World Oil Price, Lower LPG Cost
Policy: Retail Alternative Fuel Sales Mandate

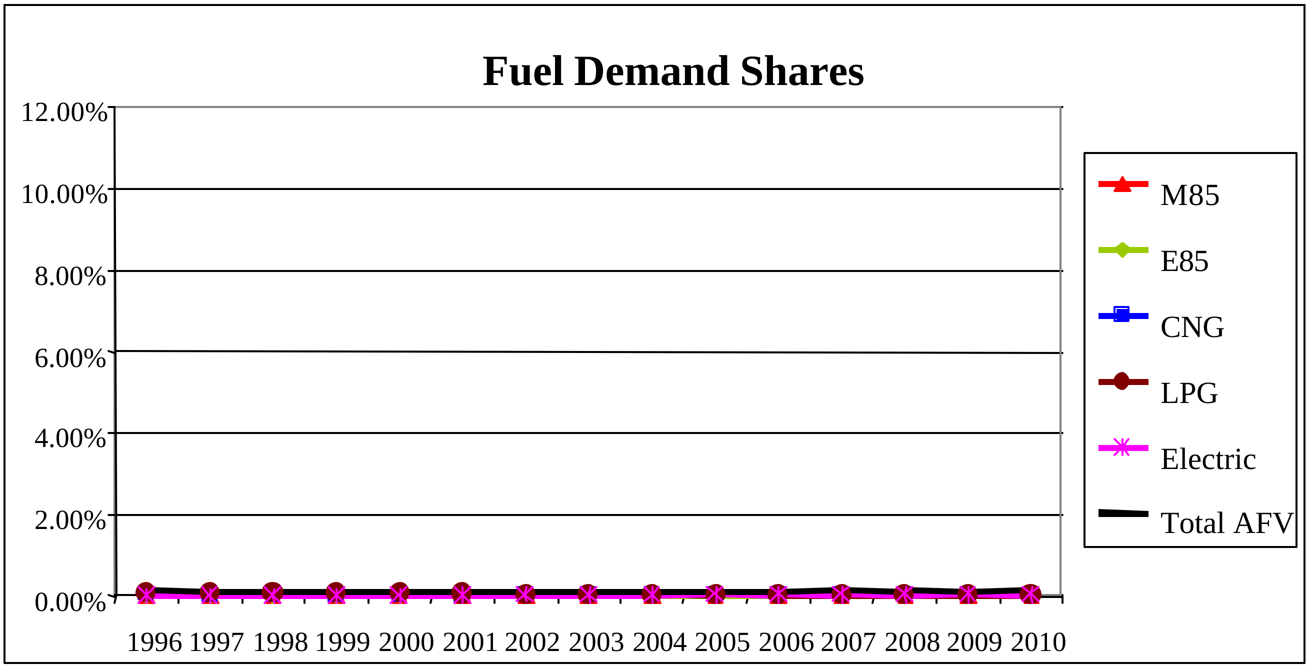


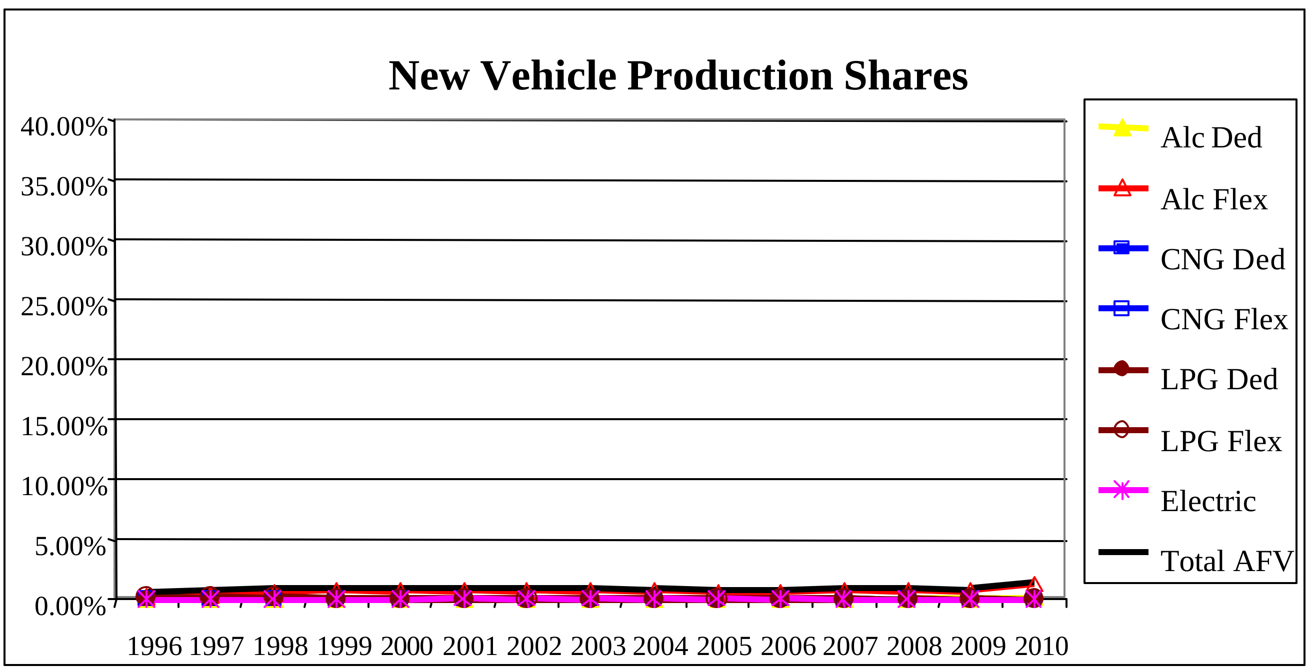


Case #67, R97FM0RS

AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted

Figure 33: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted
Policy: Retail Alternative Fuel Sales Mandate

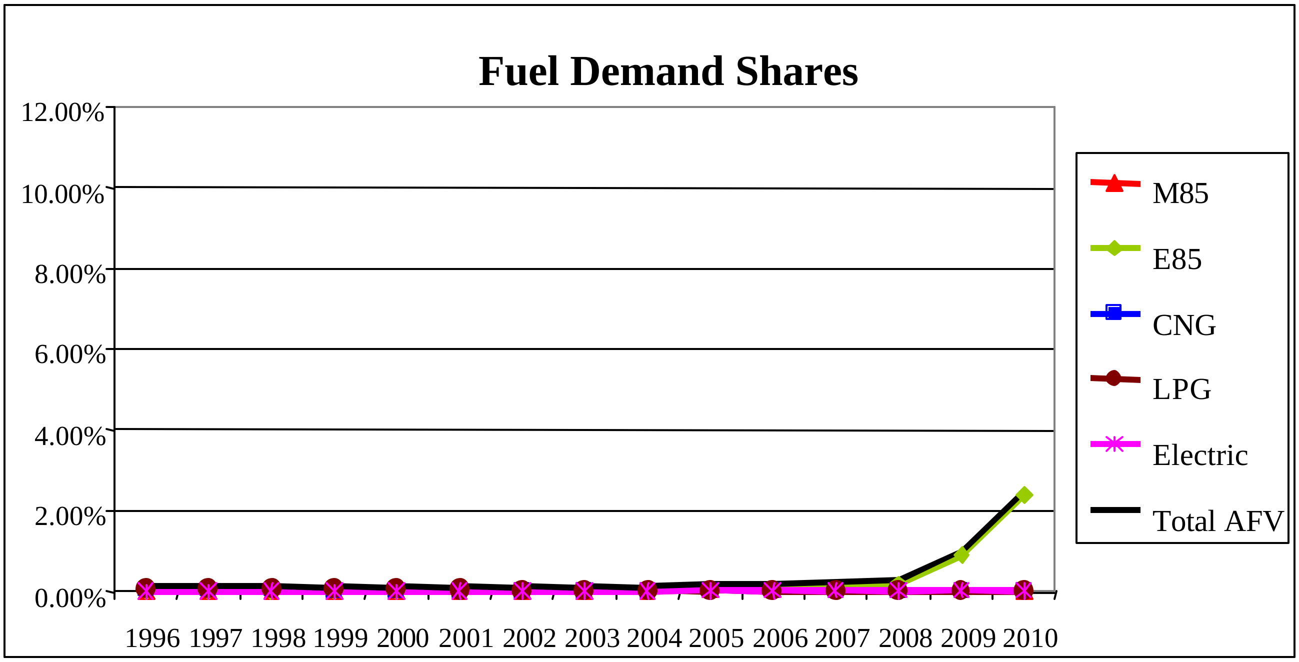


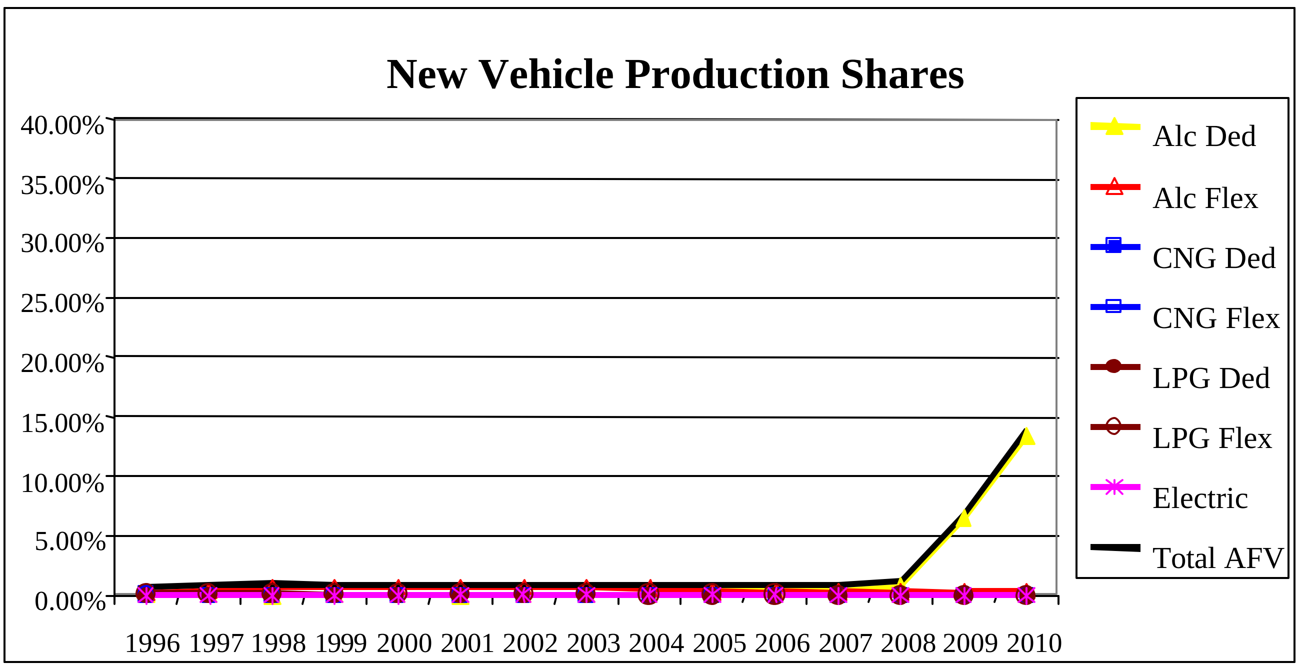


Case #4, R97TC0RS

AEO Base, Higher LPG Cost

Figure 34: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost
Policy: Continued Ethanol Tax Credit
(Scale Matches Higher World Oil Price, Tax Credits Inflation Adjusted)

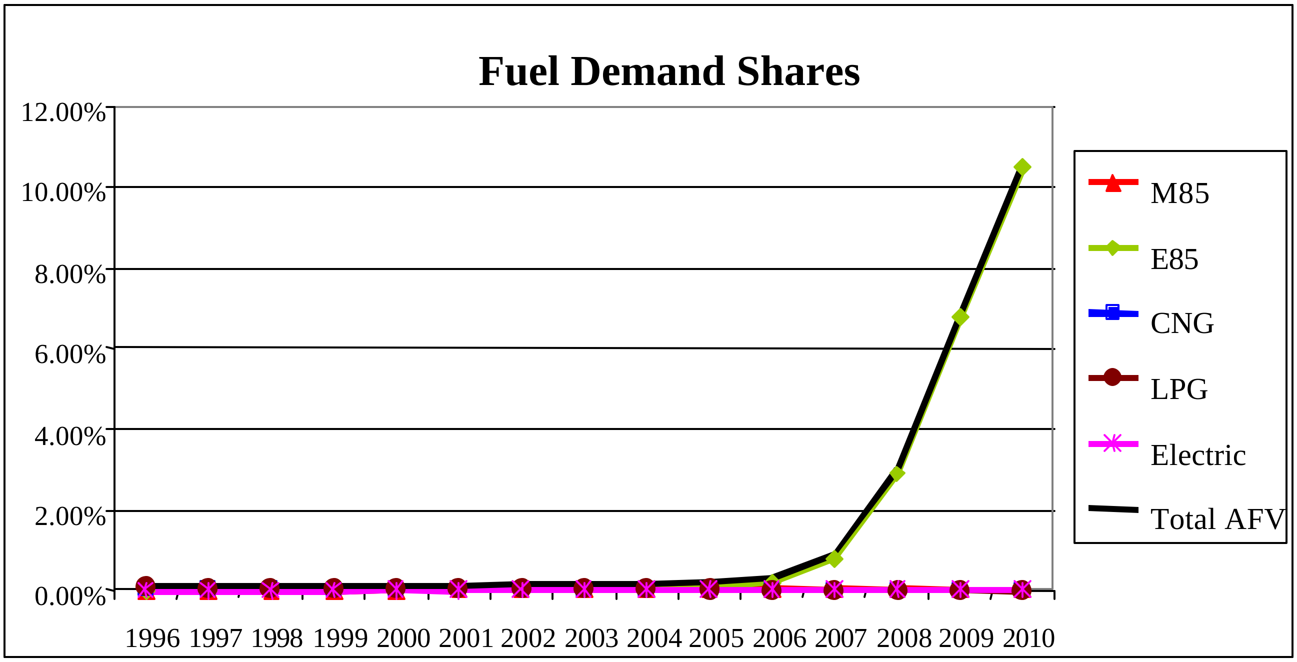


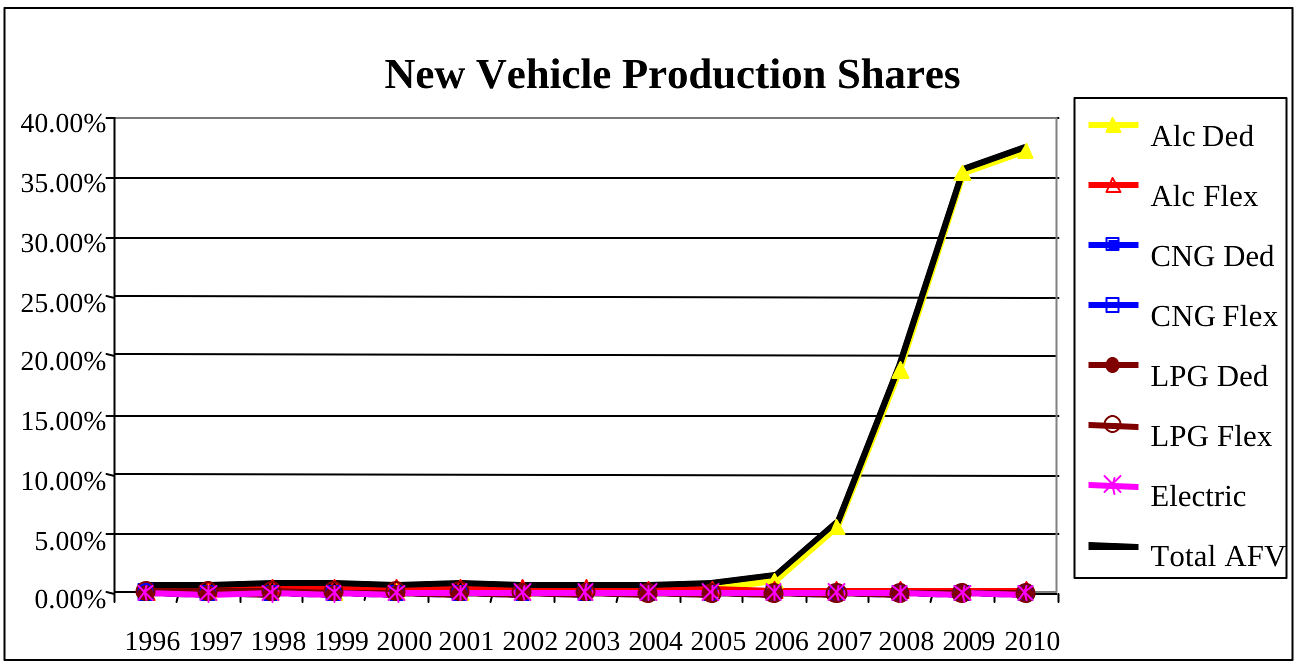


Case #64, R97TC0RS

AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted

Figure 35: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost, Tax Credits Inflation Adjusted
Policy: Continued Ethanol Tax Credit
(Scale Matches Higher World Oil Price, Tax Credits Inflation Adjusted

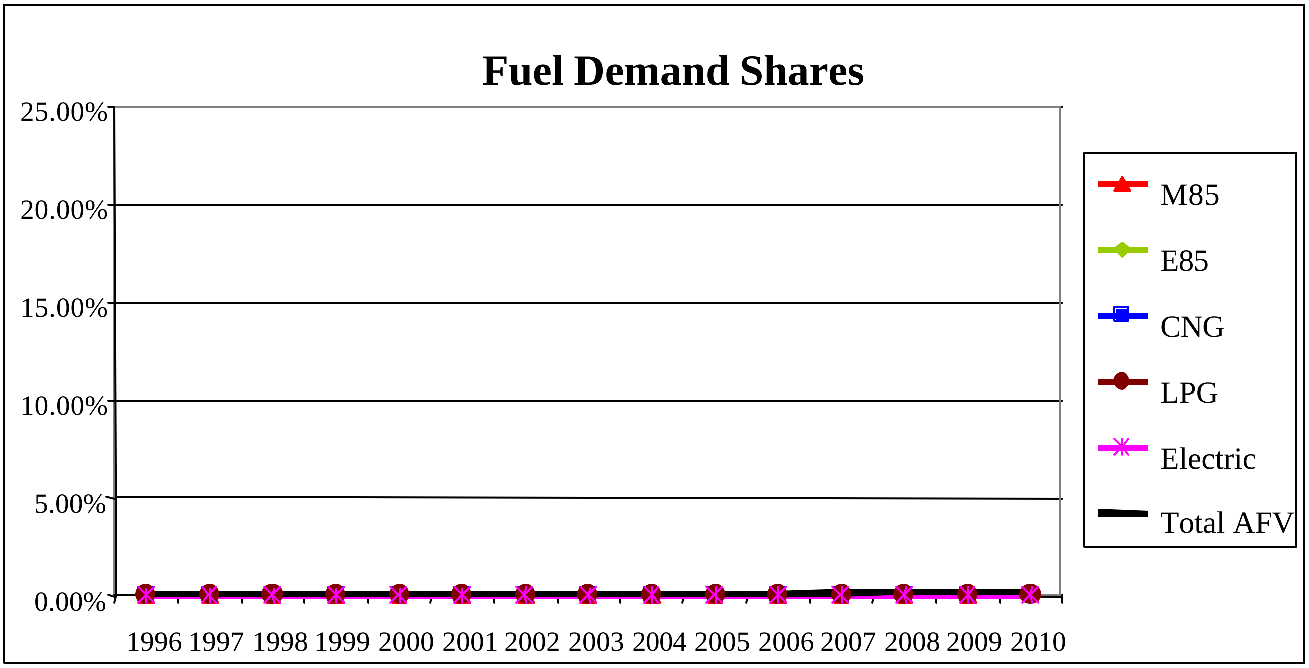


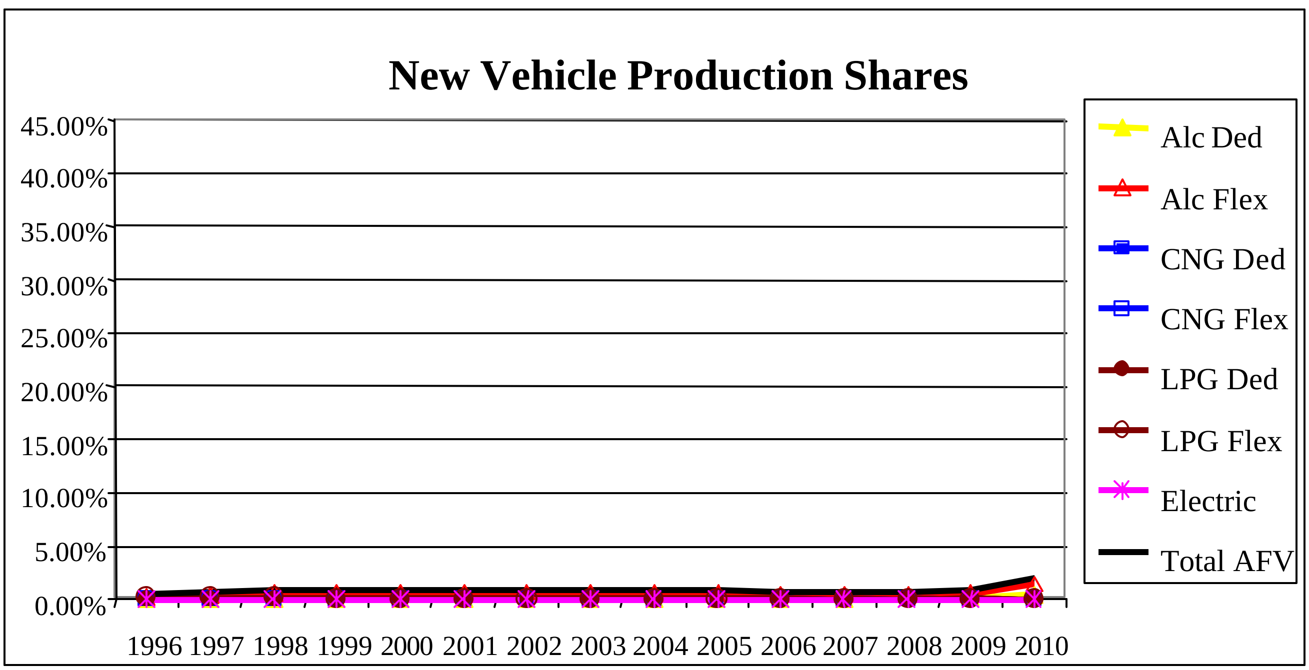


Case #28, R97TC0RS

AEO HWOP, Higher LPG Cost, Tax Credits Inflation Adjusted

Figure 36: Fuel Demand and New Vehicle Production Shares
Scenario: Higher World Oil Price, Higher LPG Cost, Tax Credits Inflation Adjusted
Policy: Continued Ethanol Tax Credit
(Enhanced Scale)

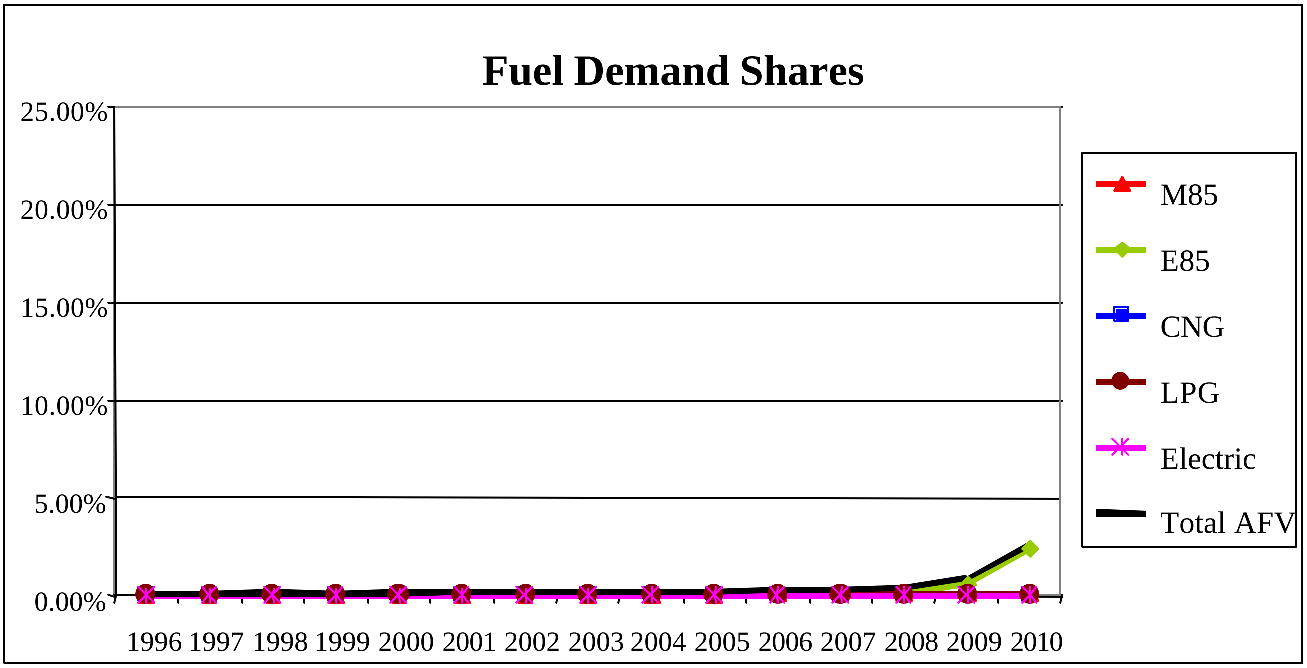


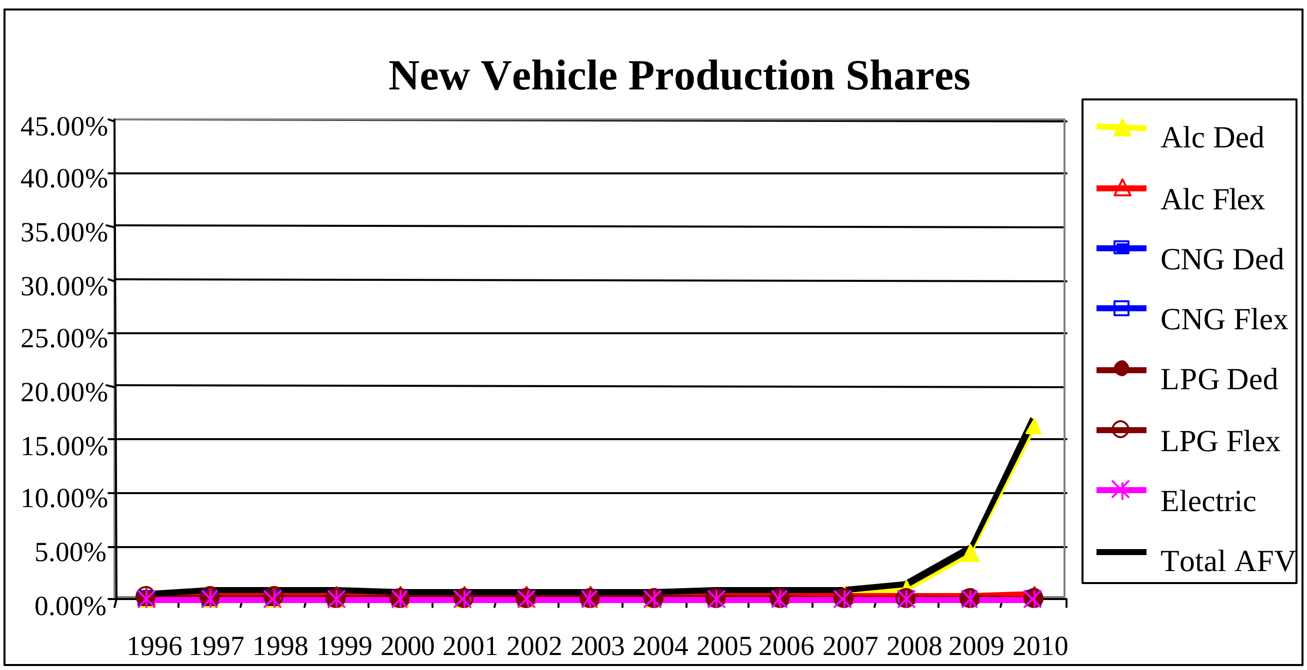


Case #5, R97GH0RS

AEO Base, Higher LPG Cost

Figure 37: Fuel Demand and New Vehicle Production Shares
Scenario: AEO Base, Higher LPG Cost
Policy: Low-GHG Fuel Subsidy
(Scale Matches Higher World Oil Price, Tax Credits Inflation Adjusted)

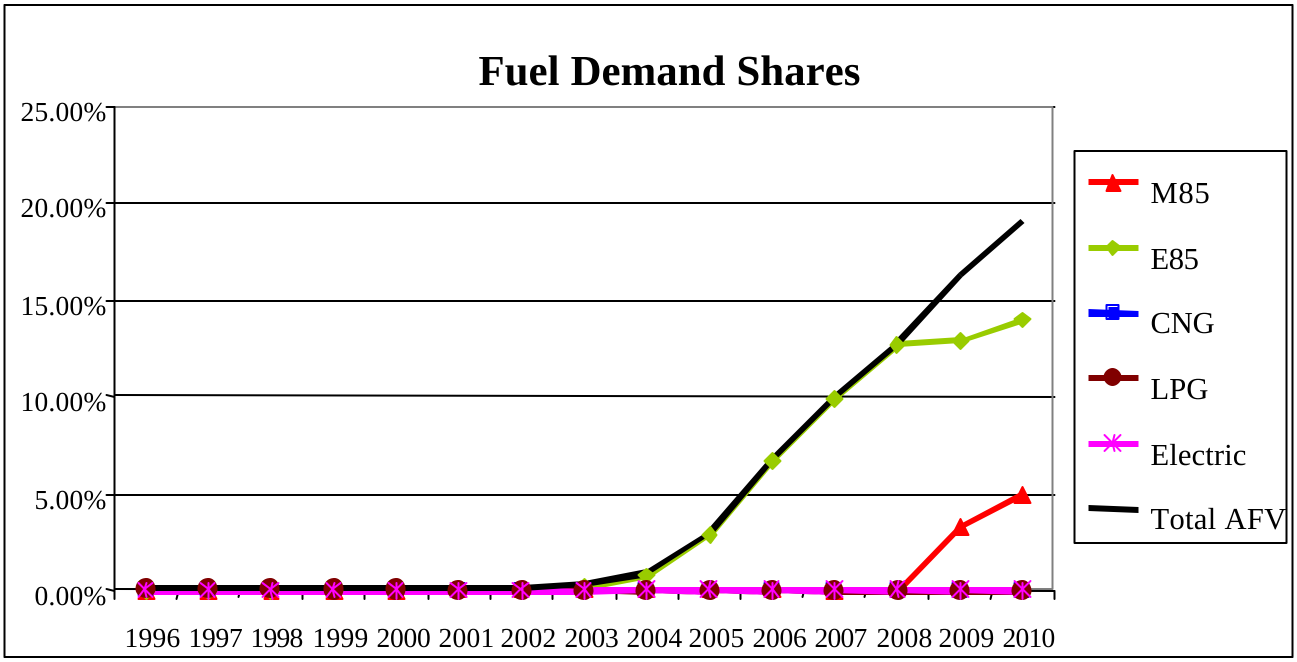


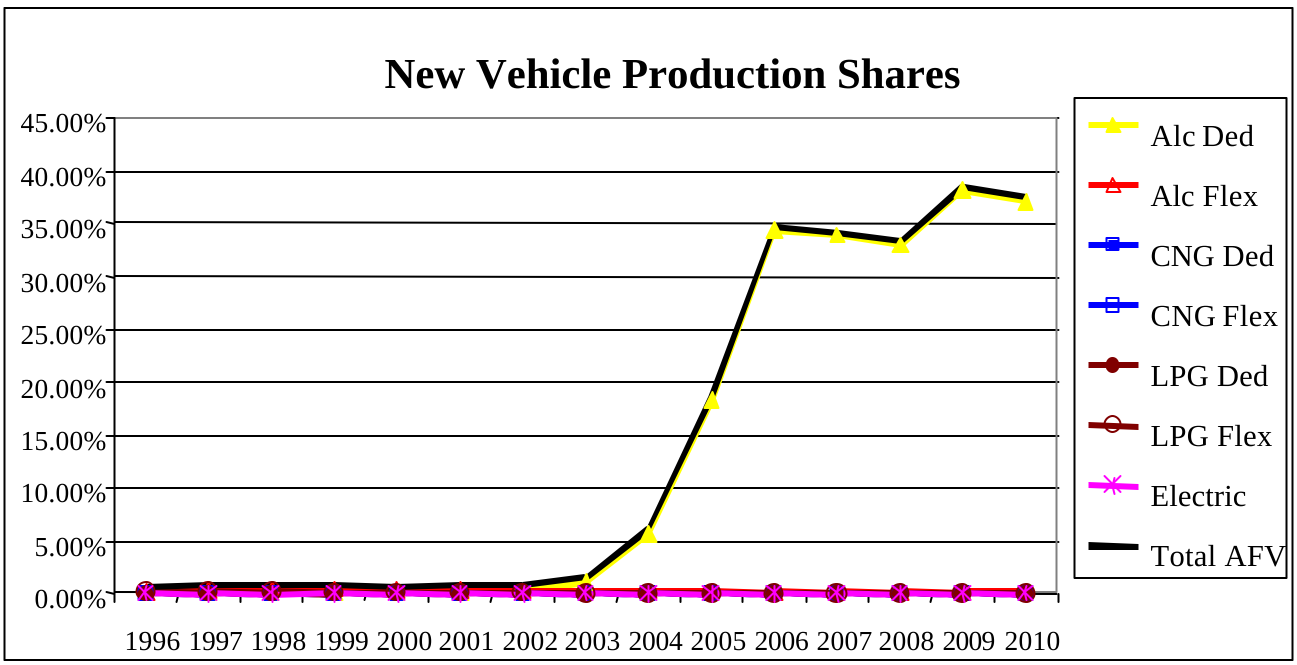


Case #41, R97GH0RS

AEO HWOP, Lower LPG Cost

Figure 38: Fuel Demand and New Vehicle Production Shares
Scenario: Higher World Oil Price, Lower LPG Cost
Policy: Low-GHG Fuel Subsidy
(Scale Matches Higher World Oil Price, Tax Credits Inflation Adjusted)





Case #29, R97GH0RS

AEO HWOP, Higher LPG Cost, Tax Credits Inflation Adjusted

Figure 39: Fuel Demand and New Vehicle Production Shares
Scenario: Higher World Oil Price, Higher LPG Cost, Tax Credits Inflation Adjusted
Policy: Low-GHG Fuel Subsidy
(Enhanced Scale)

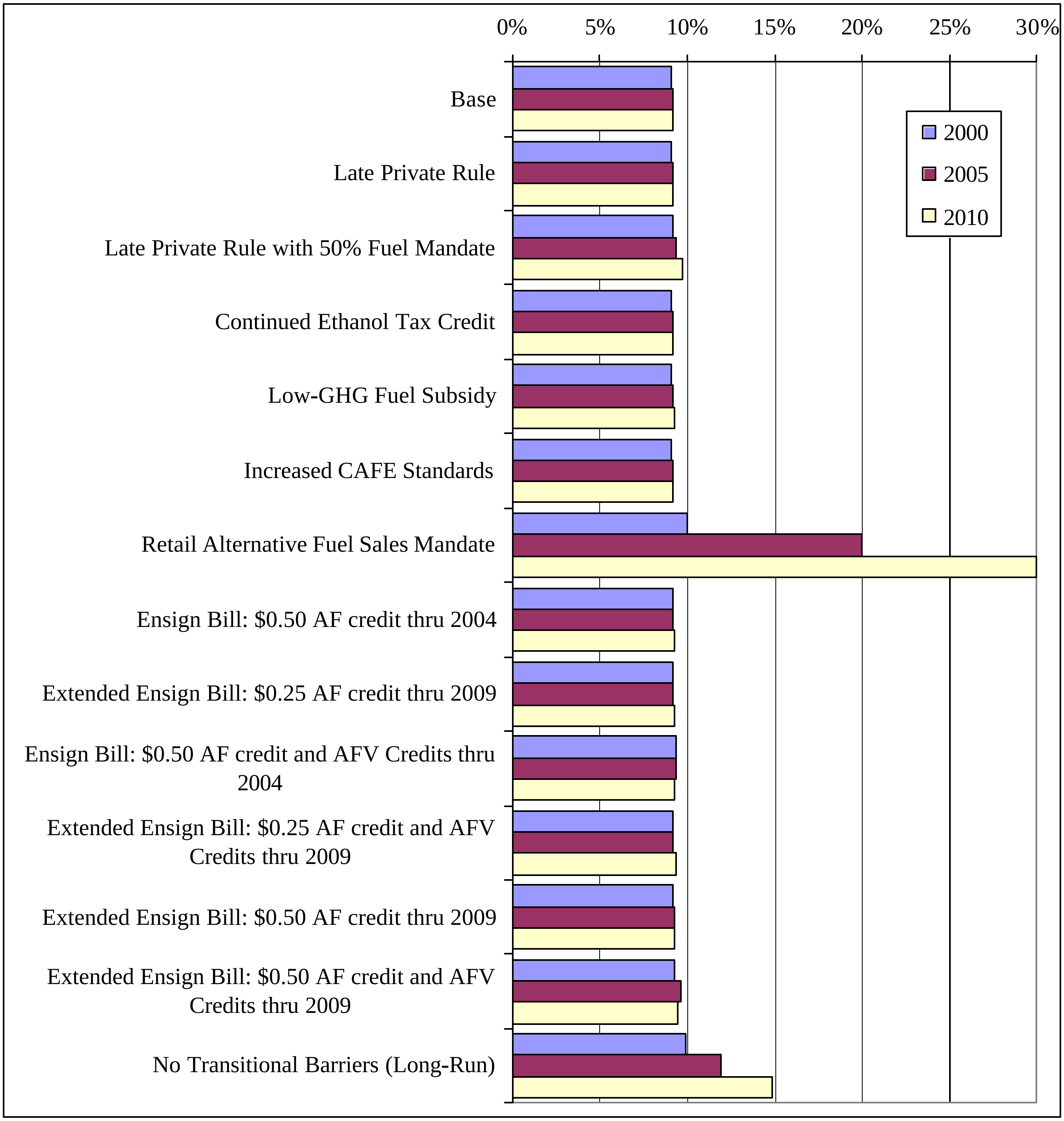


Figure 40: Gasoline Displacement by Alternative Fuels
Scenario: AEO Base, Higher LPG Cost

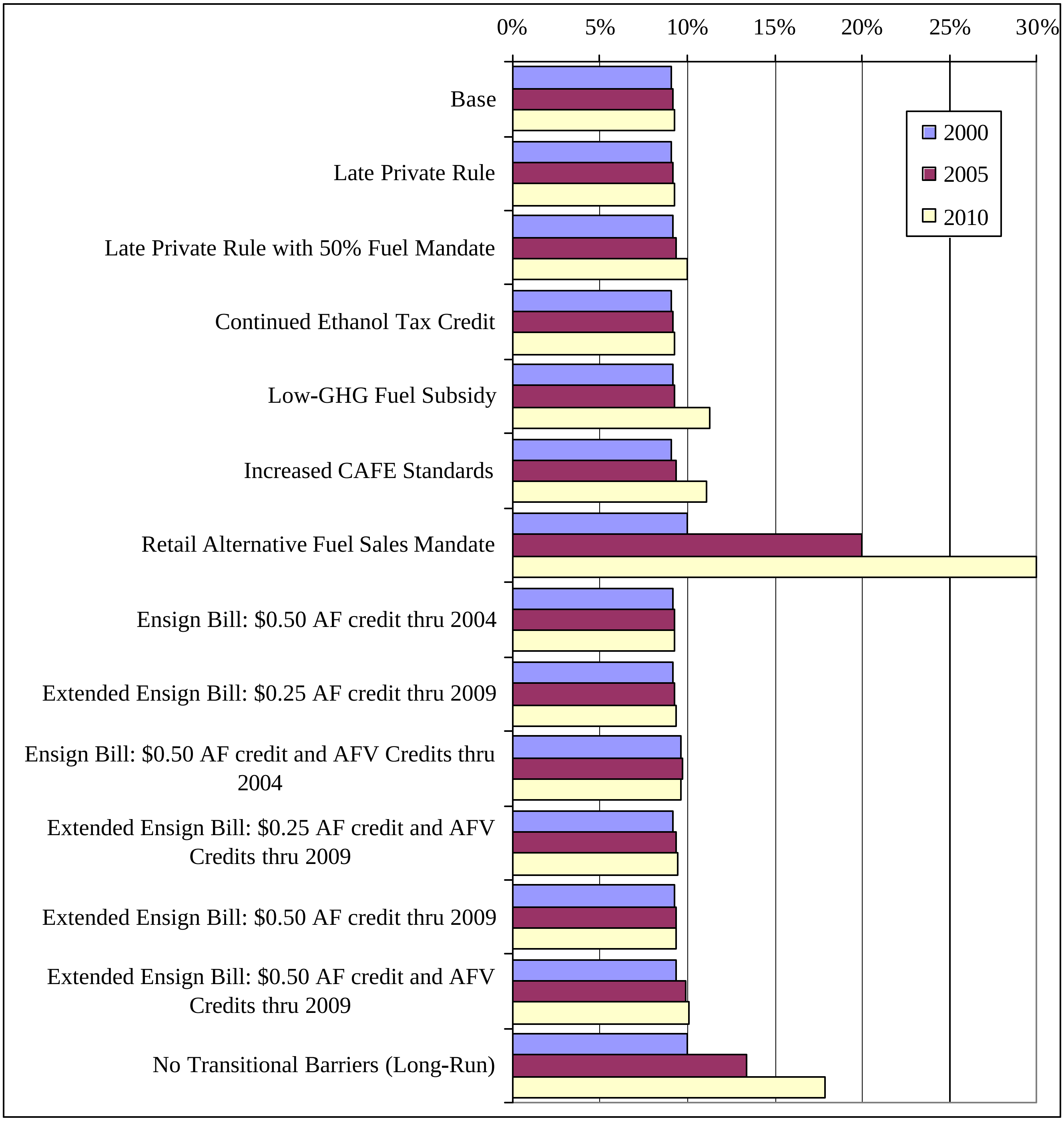


Figure 41: Gasoline Displacement by Alternative Fuels
Scenario: Higher World Oil Prices, Higher LPG Cost

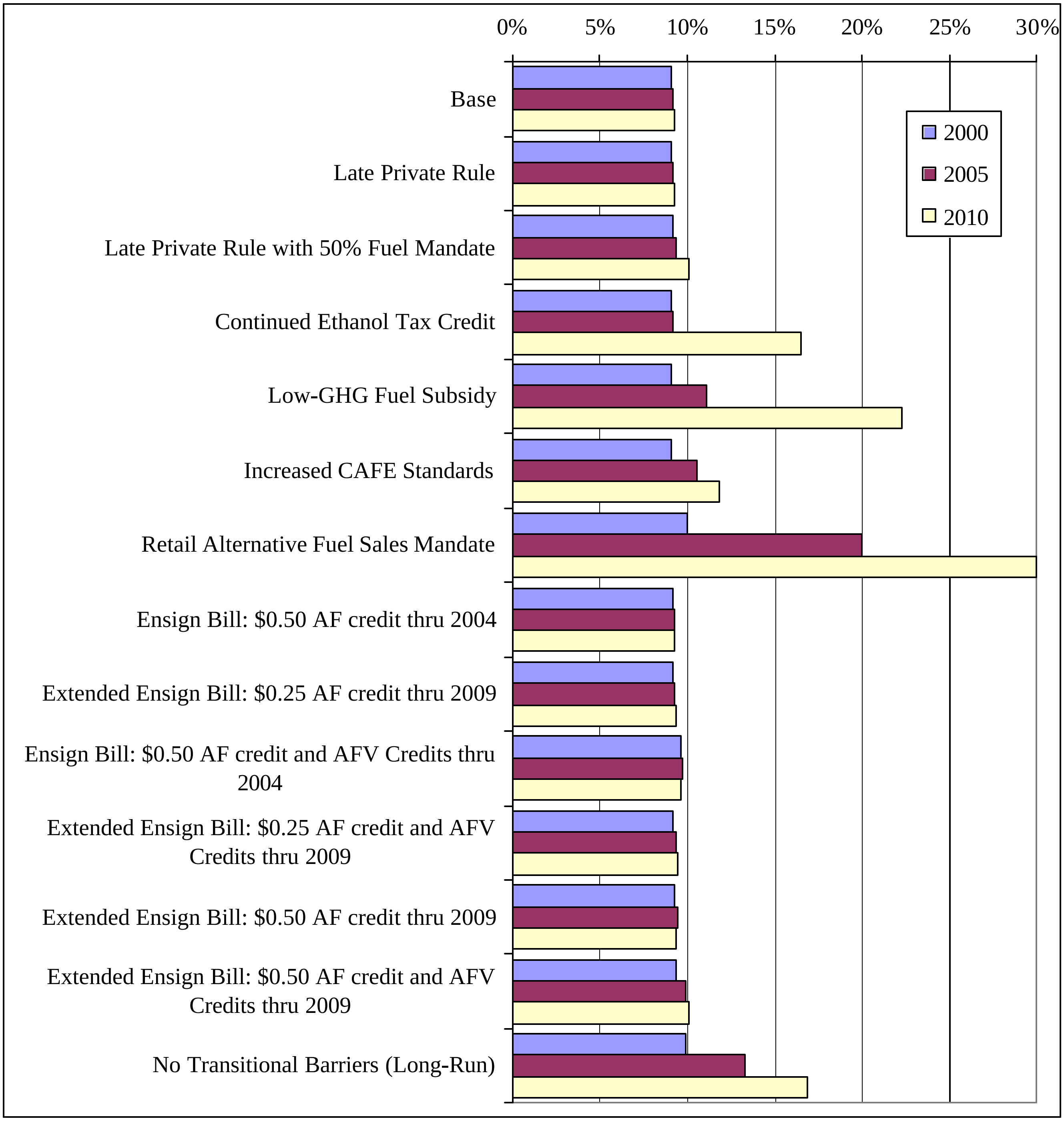


Figure 42: Gasoline Displacement by Alternative Fuels
Scenario: Higher World Oil Prices, Higher LPG Cost, Tax Credits Inflation Adjusted

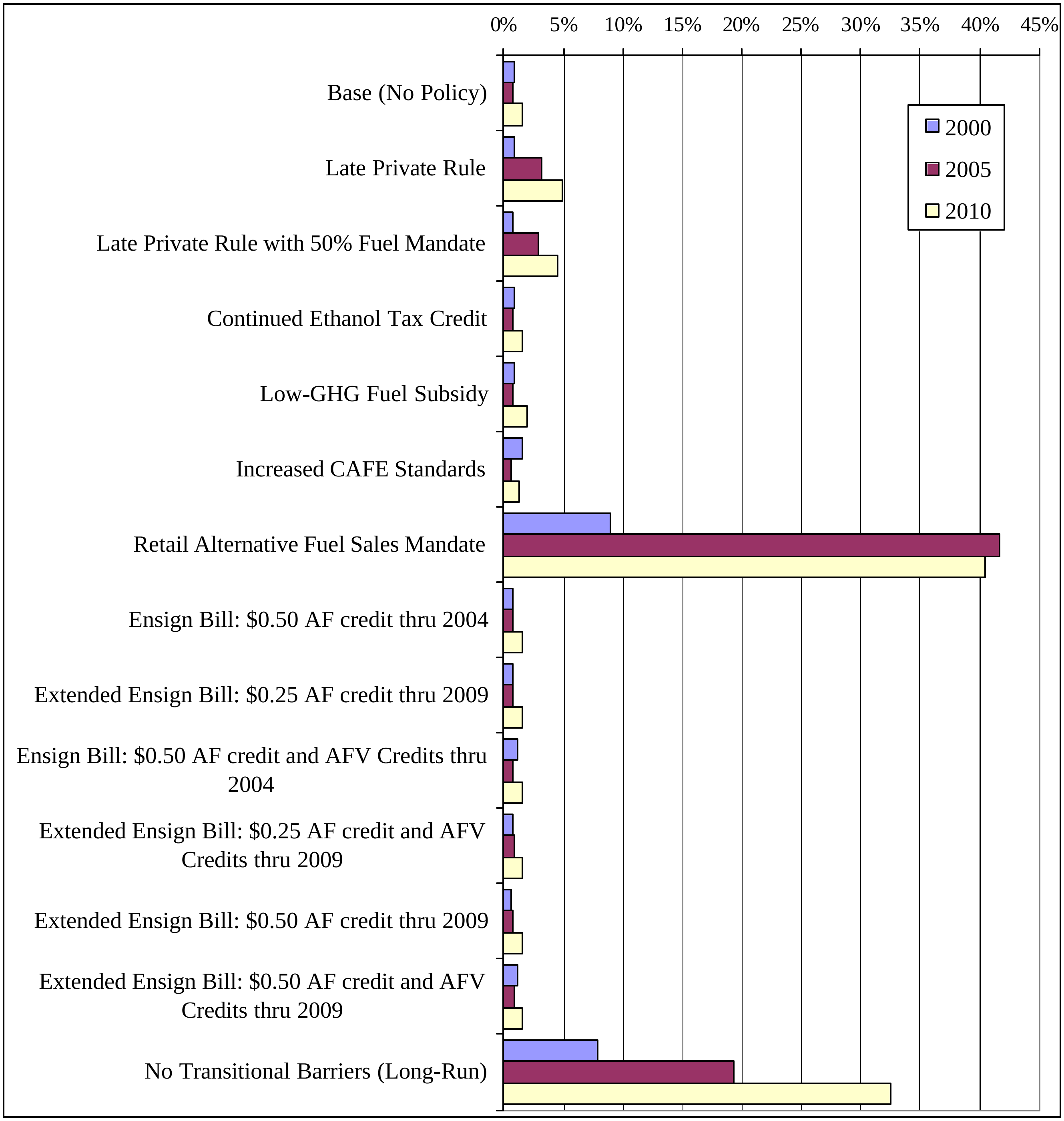


Figure 43: New AFV Demand Share
Scenario: AEO Base, Higher LPG Cost

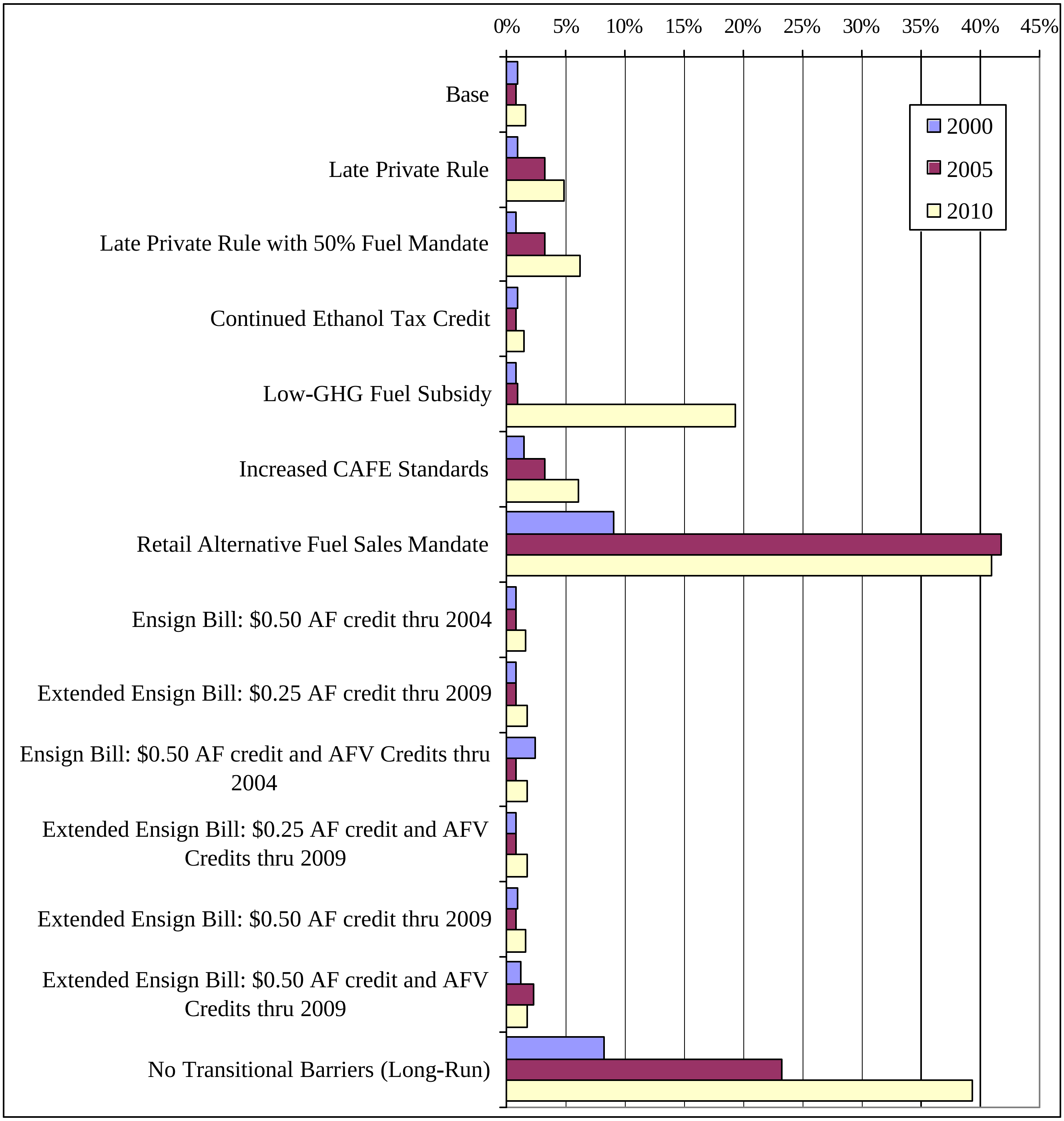


Figure 44: New AFV Demand Share
Scenario: Higher World Oil Prices, Higher LPG Cost

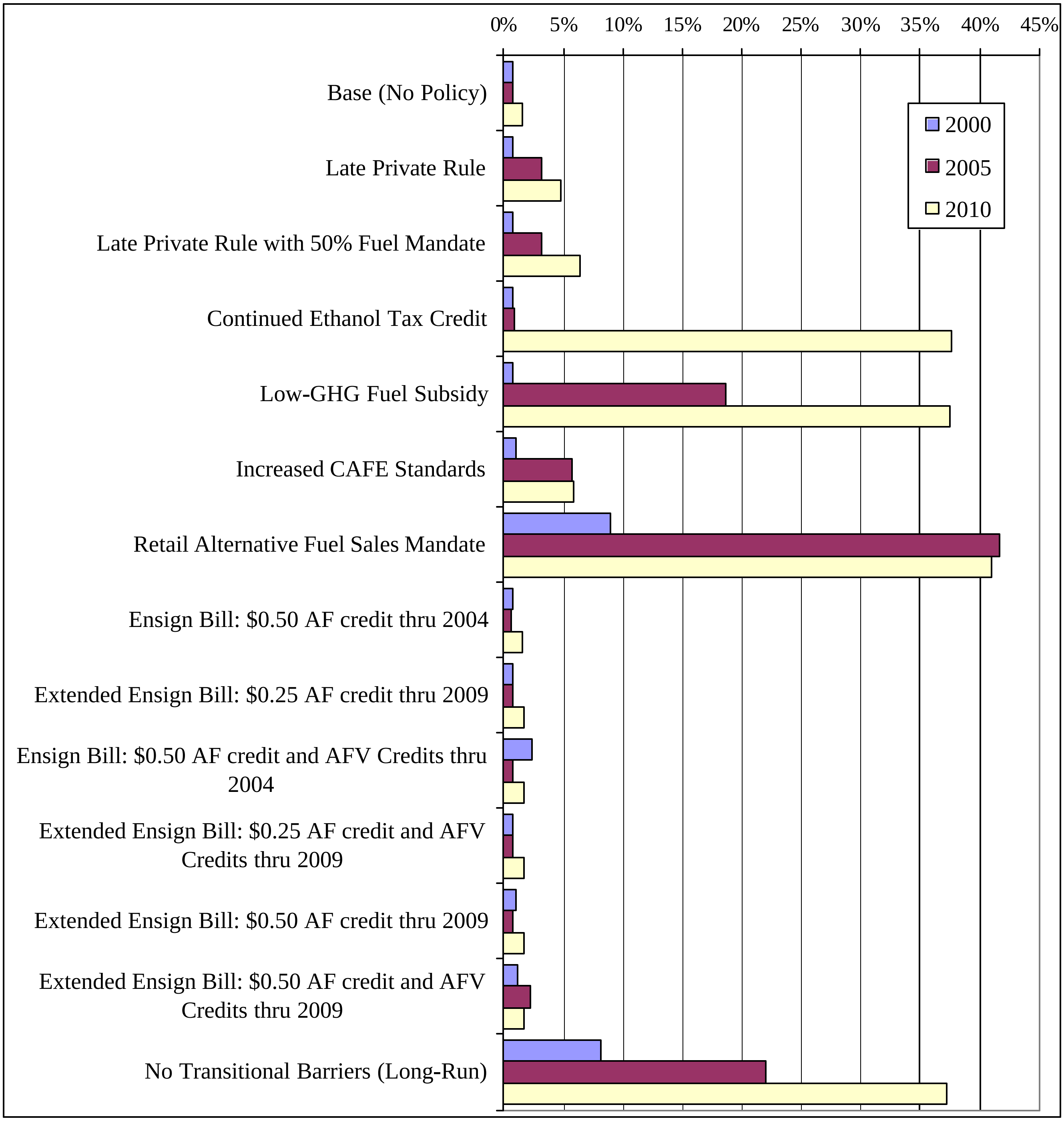


Figure 45: New AFV Demand Share
Scenario: Higher World Oil Prices, Higher LPG Cost, Tax Credits Inflation Adjusted

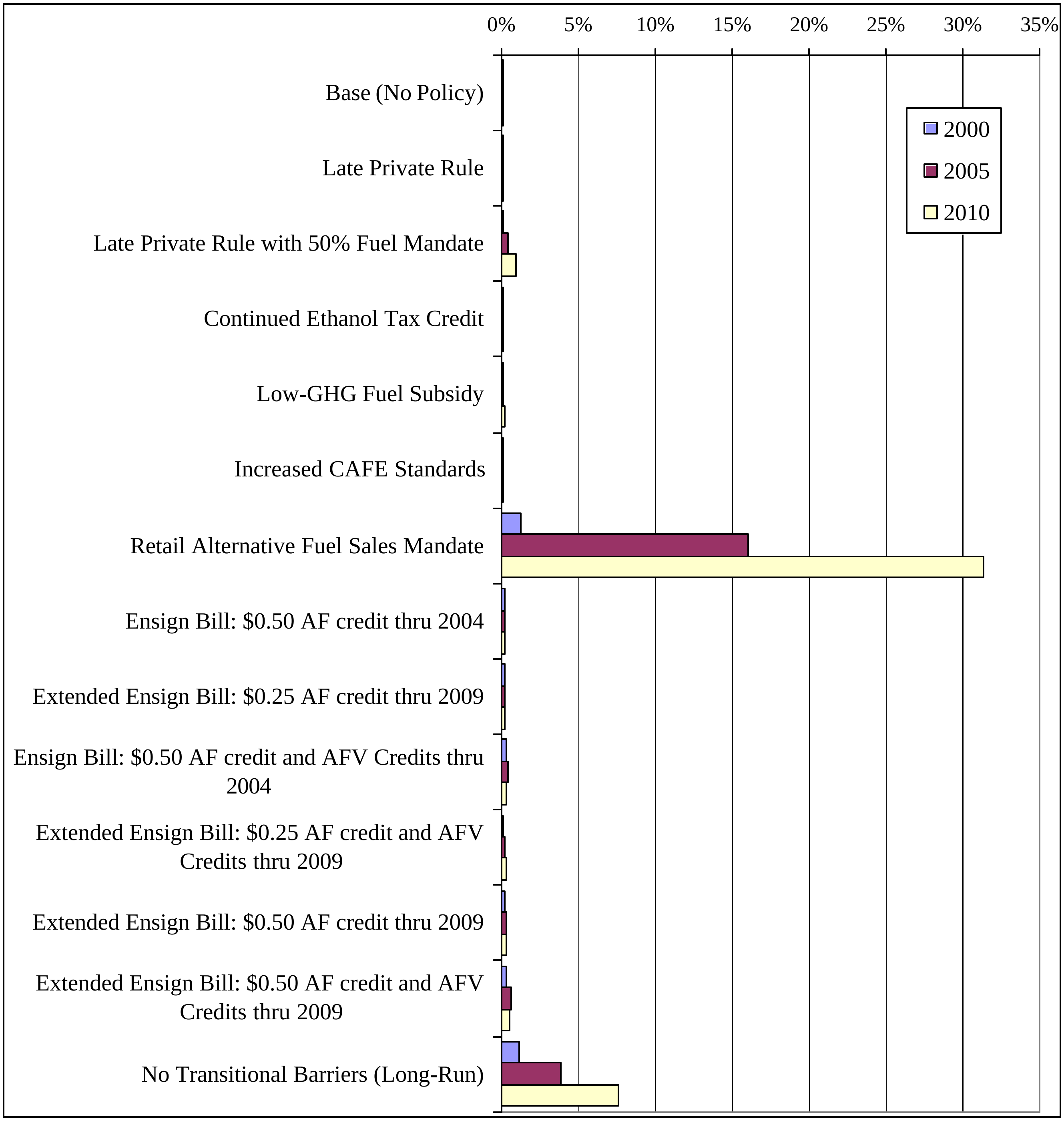


Figure 46: Alternative Fuel Demand Share
Scenario: AEO Base, Higher LPG Cost

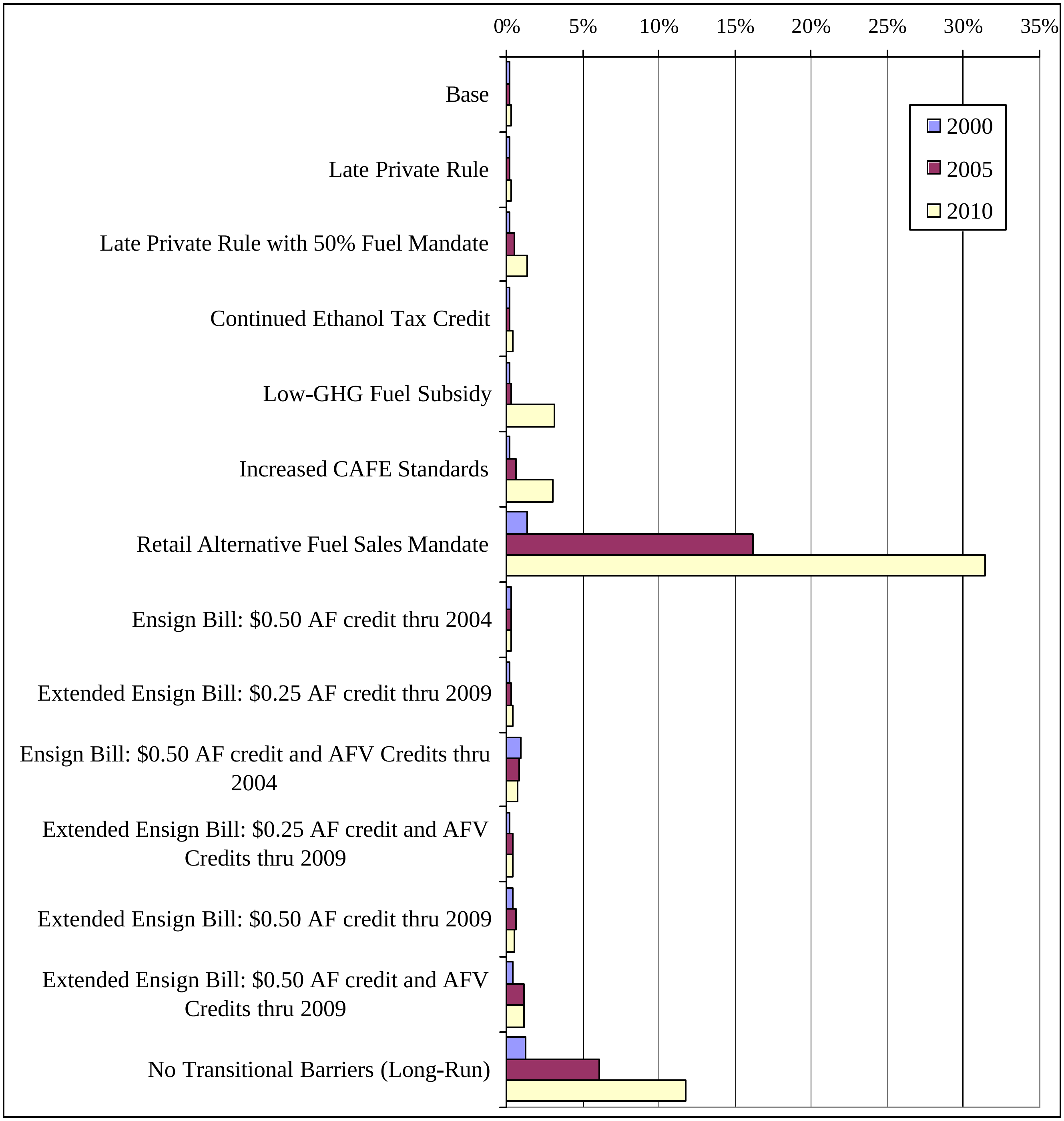


Figure 47: Alternative Fuel Demand Share
Scenario: Higher World Oil Prices, Higher LPG Cost

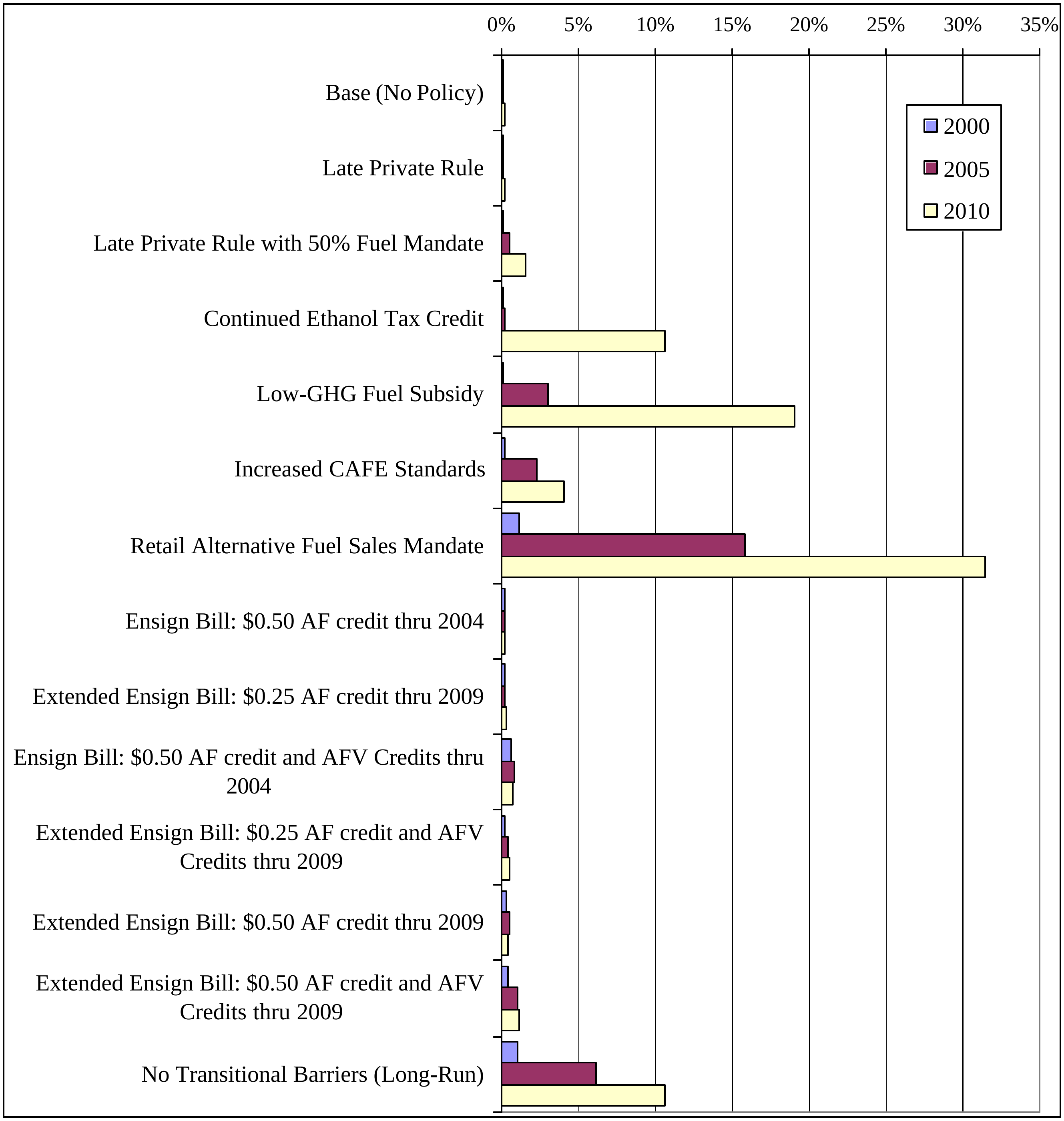


Figure 48: Alternative Fuel Demand Share
Scenario: Higher World Oil Prices, Higher LPG Cost, Tax Credits Inflation Adjusted

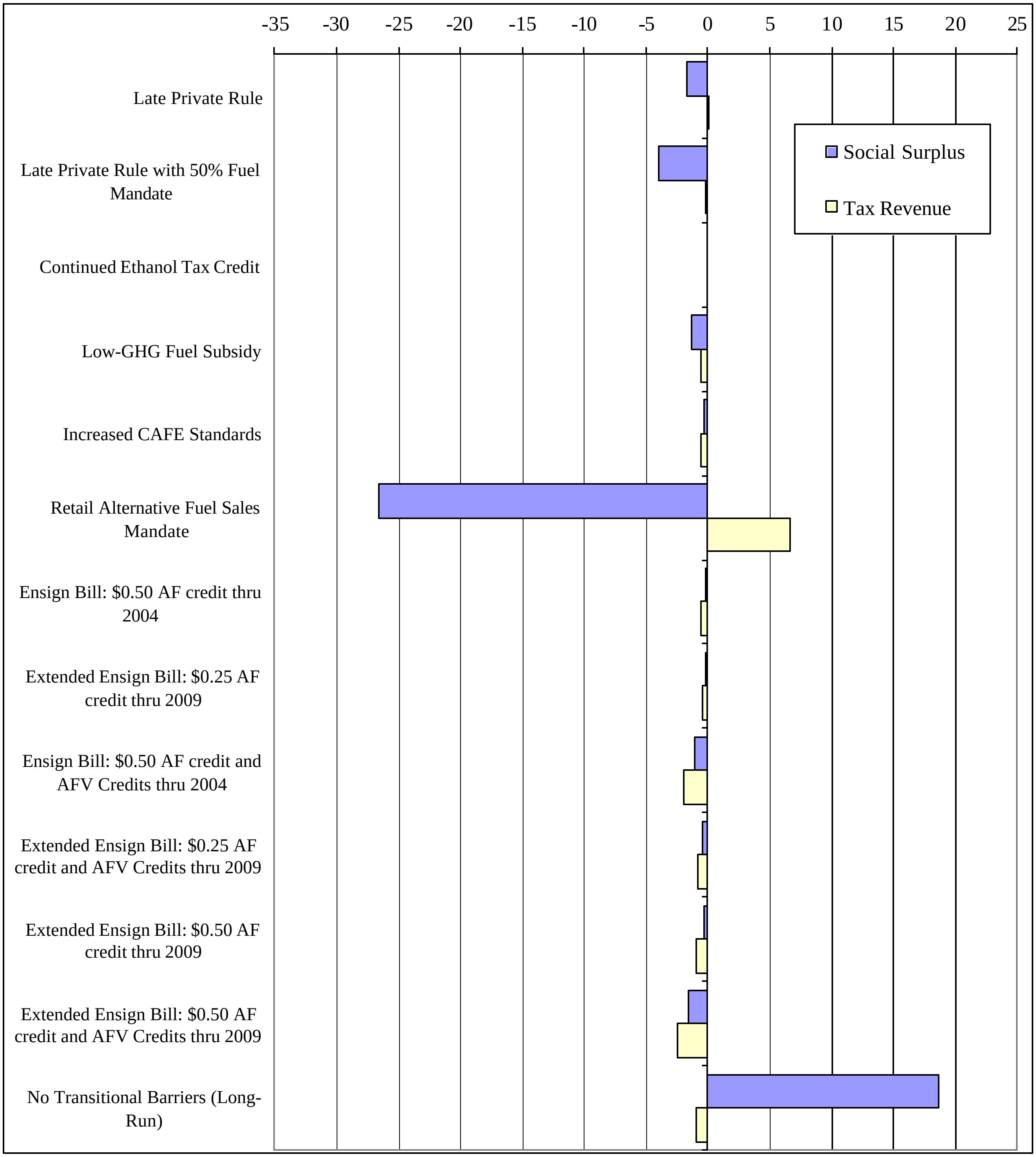


Figure 49: Net Benefits of Policies (NPV, Billions $96)
Scenario: AEO Base, Higher LPG Cost

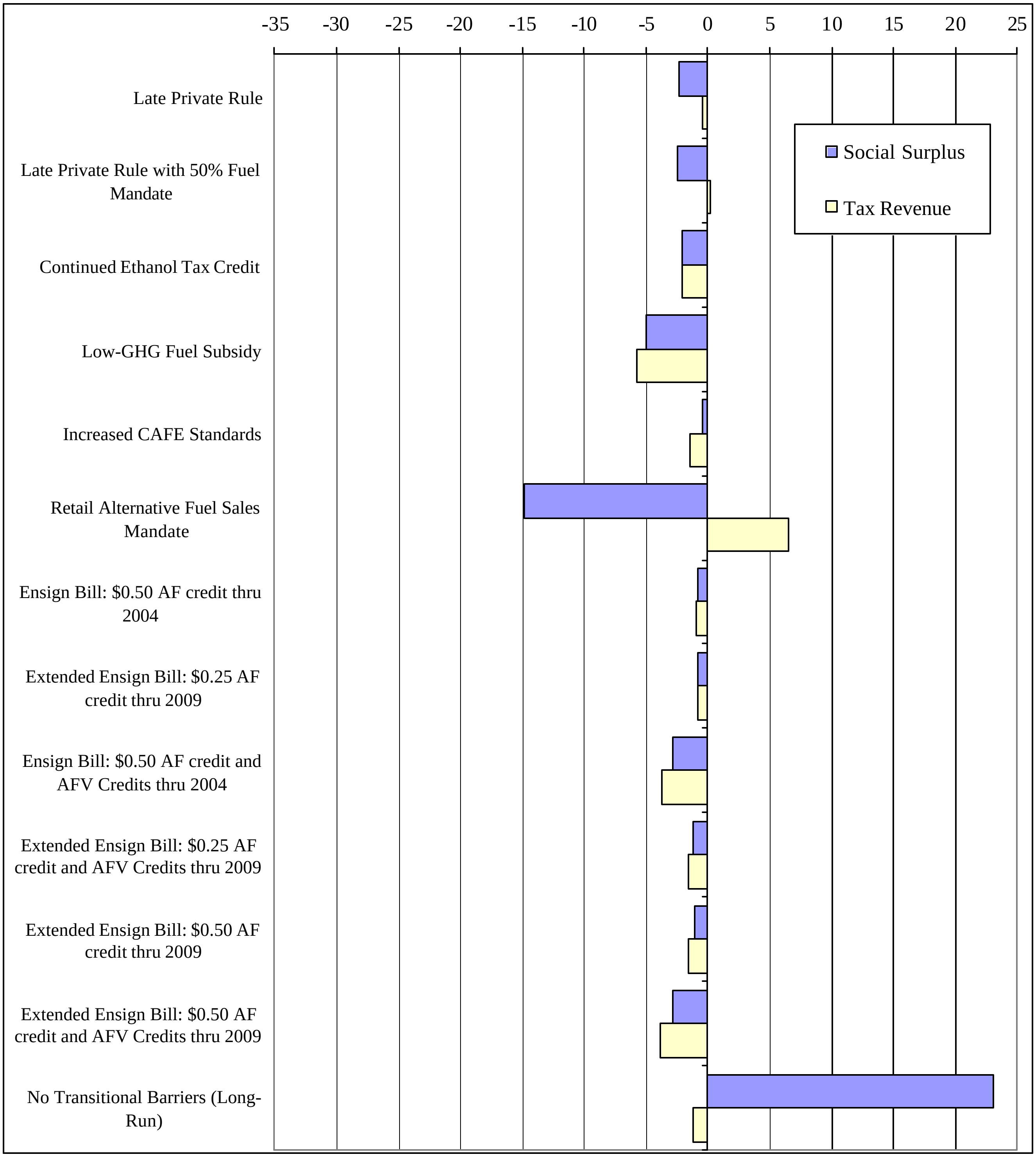


Figure 50: Net Benefits of Policies (NPV, Billions $96)
Scenario: Higher World Oil Prices, Higher LPG Cost

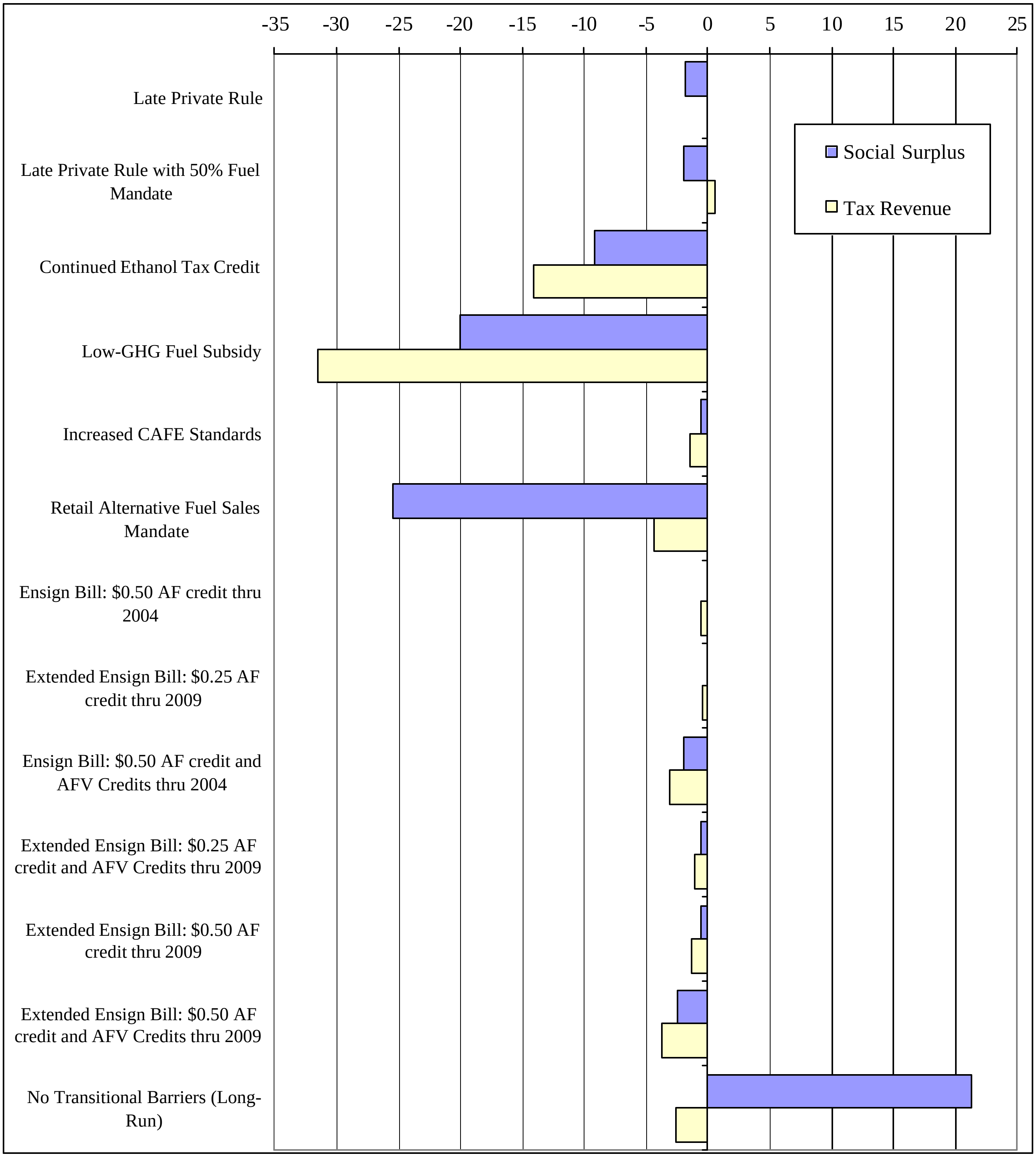


Figure 51: Net Benefits of Policies (NPV, Billions $96)
Scenario: Higher World Oil Prices, Higher LPG Cost, Tax Credits Inflation Adjusted

Appendix 4 - How to Use the TAFV Result Workbook

The TAFV Result Workbook summarizes many possible scenarios for the market introduction of alternative fuels and vehicles. The scenarios were evaluated with the Transitional Alternative Fuel and Vehicle (TAFV) Model. We hope that this workbook will be useful for conveying a large amount of information in a convenient and standardized format. It is written in visual basic and runs from within a standard Microsoft Excel workbook. To run the workbook simply open the file (currently R97rlt15b.xls) and, if requested, click on the button that says "Enable macros". [21] The workbook, TAFV Version 1.0 Result Workbook, can be downloaded from http://pzl.ed.ornl.gov/altfuels.htm.

The result book is organized with pull-down menus to choose the: "Selected Policy", "Selected Scenario", and "Selected Year". For each of the above choices, the user can chose to click on a button which shows the effect of the Private and Local Rulemaking. The variables that are available to be examined include:

Price Components	- breakdown of the effective cost of each fuel into its many components (wholesale cost, distribution costs, retailing costs, taxes, and availability costs)
AFV Share	- percentage of new vehicle demand share which is fleet AFVs, household AFVs, and total AFVs
Displacement	- percentage of gasoline use displace by each fuel (neat fuels and blends), for particular years
Fuel and Vehicle Shares	- market penetration of AFVs and Alt Fuel vs time.
Fuel Prices	- absolute an incremental fuel prices vs time
Vehicle Prices	- absolute an incremental vehicle prices vs time
Retail Availability	- share of retail stations offering each fuel vs time

The tools provided in this workbook allow you to:

Scroll up and down through the many policies and cases with arrow keys;
Select directly a particular case (by scroll box);
Scroll up and down through the years in the time horizon, for those graphs which are annual snapshots;
Select directly a particular year to display;
Adjust the scale of the graphs three different ways:
Set scale to a pre-specified uniform level, making comparisons across cases more clear;
Adjust the scale of the graphs in to automatically show maximum resolution (although care must be exercised to avoid focusing excessive attention on minor differences or variations).
Freeze the scale at the automatic (high resolution) setting for one case, to apply that same scale to other cases.

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[21] In general, never enable macros from a file that you do not know is safe from viruses.

The cases presented here are grouped into 6 scenarios of 23 policy cases. The 23 policy case are:[22]

Case	**Descriptor**
B00RS	Base
TC0RS	Continued Renewable Tax Credit
GH0RS	Low-GHG Fuel Subsidy
CA0RS	Increased CAFE Standard
FM0RS	Retail Alternative Fuels Sales Mandate
EN0RS	Ensign Bill: 50 cent AF credit thru 2004
EX0RS	Extended Ensign Bill: 25 cent AF credit thru 2009
EN1RS	Ensign Bill: 50 cent AF credit and AFV Credits thru 2004
EX1RS	Extended Ensign Bill: 25 cent AF credit and AFV Credits thru 2009
EX2RS	Extended 50c Ensign AF Bill: 50 cent AF credit thru 2009
EX3RS	Extended 50c Ensign AF/AFV Bill: 50 cent AF credit and AFV Credits thru 2009
BNBRS	No Transitional Barriers case (long run)
P00RS	Late Private Rule Implementation
P01RS	Late Private Rule With 50% Fuel Use
PENRS	P&L Rule Plus Ensign AF Bill: 50 cent AF credit thru 2004
PEXRS	P&L Rule Plus Extended Ensign AF Bill: 25 cent AF credit thru 2009
PTCRS	P&L Rule Plus Continued Ethanol Tax Credit
PGHRS	P&L Rule Plus Low-GHG Fuel Subsidy
PCARS	P&L Rule Plus Increased CAFE Standard
PE1RS	P&L Rule Plus Ensign AF/AFV Bill: 50 cent AF credit and AFV Credits thru 2004
PX1RS	P&L Rule Plus Extended Ensign AF/AFV Bill: 25 cent AF credit and AFV Credits thru 2009
PX2RS	P&L Rule Plus Extended 50c Ensign AF Bill: 50 cent AF credit thru 2009
PX3RS	P&L Rule Plus Extended 50c Ensign AF/AFV Bill: 50 cent AF credit and AFV Credits thru 2009

The cases in the Result Book are the above 23 policy cases, with 6 over-arching scenario assumptions:

AEO98 Oil Prices	**LPG Costs**	**Ethanol Tax Credits**	**Oil Price Shock?**
Base	Higher	Constant Nominal	No
HWOP	Higher	Constant Nominal	No
HWOP	Higher	Constant Real	No
HWOP	Lower	Constant Nominal	No
Base	Higher	Constant Nominal	Yes, 2005

[22]Not every scenario is matched with every possible sensitivity and price assumption. For example, the Fuel Mandate Case is not run assuming that the Private and Local Rulemaking has also been put into effect.

Base	Higher	Constant Real	No

1.Federal tax rates pursuant to the Taxpayer Relief Act of 1997 apply before September 30, 1999. These tax rates do not reflect the October 1, 1999 changes to the federal tax code. The columns may not sum do to rounding.

2.Conversion factors are given in Appendix 2.